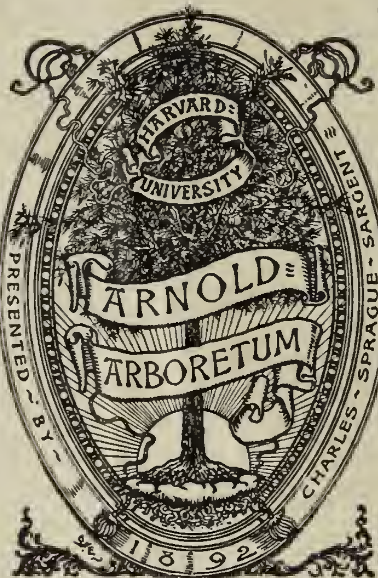
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1892

VOL. II PART I

THE

INDIAN FOREST RECORDS

On some Insect Pests of the Himalayan Oaks (Quercus dilatata and Q. incana)

By E. P. STEBBING, F.L.S., F.Z.S., F.R.G.S., F.E.S.,
Impl. Forest Zoologist to the Govt. of India

Published by Order of the Government of India

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
Published in August 1909

Price annas 6 or 7d.

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INDIAN FOREST RECORDS.

Vol. II.] 1909. [Part. I.

On Some Insect Pests of the Himalayan Oaks (Quercus dilatata and Q. incana).

GENERAL.

In the year 1868 a small pamphlet entitled "Insects destructive to Woods and Forests"* from the pen of Mr. R. Thompson, lately Conservator (then Assistant Conservator) of Forests, was issued by the Government of the United Provinces. This small brochure was the first thing of its kind to appear and showed its author to be possessed of remarkable powers of observation, although the system of classification adopted renders the identification of many of the insects dealt with a matter of some difficulty. Whilst there is much that is absolutely correct in every detail in the small monograph, a note on the subject of pests infesting the oak trees at Naini Tal would appear to have been written in the absence of that first hand knowledge from personal observation which is so apparent elsewhere in the pamphlet.

Writing on the subject of the *Lucanidæ* or Stag beetles Mr. Thompson stated "The Stag beetles are both numerous and common in individuals and are, of the whole order of wood beetles, the most destructive to living trees. Some idea may be formed of the ravages of these insects when it is stated that the larvæ live from three to four years in that state in the interior of the trunks of oaks, and that barely one in ten of the trees to be met with in Naini Tal does not bear the marks of their ravages. These

* Report on Insects destructive to Woods and Forests, by R. Thompson, Assistant Conservator, Garhwal Forests. (Allahabad Government Press, North-Western Provinces, 1868.)

and larvæ of Prionus beetles seem exclusively to attach themselves to the oak as their habitation. They bore circular chambers, penetrating to the heart of the stem and winding into various passages both up and down the trunk. They eject the undigested particles through holes made for the purpose, forming lateral communications with the main tunnels." Some twenty years ago Mr. Walter F. Blandford, Lecturer on Entomology at the R. I. E. College, Coopers Hill, first drew attention to this statement of Mr. Thompson's on the subject of insect attacks in the Naini Tal oaks. Mr. Blandford had never visited India, but in commenting upon Mr. Thompson's assertion he pointed out that it was quite impossible that hard oak wood could be tunnelled into by the larvæ of *Lucanidæ* in the manner detailed.

Incidentally it may be mentioned that this family does not contain the worst beetle pests. The larvæ of lamellicorns, to which group the *Lucanidæ* grubs belong, are bulky curved insects, the hinder segments consisting of a soft swollen kind of bag or sac. Whilst a grub so built could move slowly about in tunnels in rotting wood, it would be quite impossible for it to do so in hard wood.*

For some years subsequent to its appearance this statement of Mr. Thompson's as to the cause of the damage to the oaks at Naini Tal and elsewhere in the Himalayas was received and quoted in India as an accepted and undisputed fact.† In *Injurious Insects*‡ I pointed out that the galleries said to be made in the oaks by the Stag beetle grubs were more probably the work of the '*Prionus*' larvæ (a Cerambycid) than that of the Lucanid ones, but the real cause of the diseased condition of the trees in the station has remained an open question round which a certain amount of speculation has arisen. As will be seen later, it is now believed that the galleries in the oak wood are made by the larvæ of a Cerambycid.

That this is the view now held by the Manager of the Brewery at Jeolikote near Naini Tal is borne out by the fact that he recently forwarded to the office of the Imperial Forest Zoologist some Cerambycid grubs and specimens of oak timber from galleries in which they had been taken, with a request for the identification of the pest.

In the following pages I propose to describe, from investigation and

* For a full description and illustrations of the Stag beetle and lamellicorn larvæ *vide* my Manual of Forest Zoology for India, p. 79 and figs. 132*a*, 137, 138, and 143*a*.

† *Vide* Indian Museum Notes, Vol., II, p. 148.

‡ Injurious Insects of Indian Forests, p. 32.

studies conducted personally in the field, the life histories so far as at present known of some of the more dangerous insect pests infesting the two Himalayan oaks, *Quercus dilatata,* known in the vernacular as the *morú* oak, and *Quercus incana,* known as the *bán* oak. The insects dealt with are all save one members of the bark and wood boring families *Buprestidæ, Cerambycidæ, Scolytidæ* and *Platypidæ,* four of the most dangerous families of beetles to the forests of the country.

The Buprestidæ contain one species, Amorphosoma ? sp.

The Cerambycidæ three, *Lophosternus hugelii, Xylotrechus smeei* and *Xylotrechus stebbingi,* Gahan.

The *Scolytidæ,* including the *Platypidæ,* contain 5 species: a new species of *Sphaerotrypes,* which I call *S. querci;* a new species of *Dryocœtes* which I name *D. Hewetti* after Sir John Hewett, the life histories of which are both here described for the first time, a species of *Chramesus,* and the two Platypids *Diapus impressus* and *Diapus* sp. prox. *impressus.*

The only other insect to be treated of here will be the newly discovered Scale insect *Kermes himalayensis,* Green, which was found killing the bán oaks above, and to the north of, Bhim Tal. The discovery of this insect is of high interest both scientifically and economically. It is the first report of the existence of the genus *Kermes* in India, whilst owing to its method of attack and great powers of rapid increase the scale must be regarded as a serious pest.

As regards other known pests of these oaks I have already detailed in *Departmental Notes** the life history of the leaf-roller and defoliating weevil *Apoderus incana,* Steb., whilst Mr. B. O. Coventry, I.F.S., in an excellent paper in the *Indian Forester,*† dealt fully with the life history of the bán acorn weevil tunneller *Calandra sculpturata,* Gyll., which is responsible for so little natural regeneration of this tree being found in some parts of the Western Himalayas.

Investigations have also been made into several twig and leaf galls made upon these two oaks by as yet undetermined hymenopterous flies, probably Chalcids.

Little is known at present on the subject of the lepidopterous defoliating caterpillar pests of these two oaks.

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*Stebbing, *Departmental Notes on Insects that affect Forestry,* Vol. I, p. 189.
†*Indian Forester,* Vol. XXVIII, No. 10 (November, 1902).

Part I : THE BUPRESTID BEETLE OF THE OAKS.

AMORPHOSOMA ? sp.

(The Oak Buprestid beetle.)

Nature of Attack.

The egg is probably laid in a crevice or depression on the bark of the oak. The grub on hatching out bores down through the bark to the bast layer and eats out in this an irregular winding gallery which grooves both bast and sap wood. The larval galleries destroy the bast, and when numerous the insect helps to kill the tree.

Previous Record of Insect.

I have no previous record of reports of this insect. I first took larvæ of the species in Jaunsar, North-West Himalayas, in 1902.

Distribution.

The insect is fairly plentiful in Naini Tal and throughout Kumaun. It is probably spread throughout the *Moru* and *Ban* oak areas of the Western Himalaya.

General Appearance.

Larva or Grub.—The larva is yellowish white, flat, elongate, with narrow body segments and a large circular segment immediately following the small yellow head; the segments following this large prothoracic segment are of equal size save the last which tapers slightly posteriorly. The grub is one inch in length, and in its gallery it is often found curled up, the posterior segments lying almost in contact with those immediately below the large one. Plate I, figs. 1, 1*a*, show the larva dorsal and side view.

Beetle.—The beetle is a small insect of brilliant green metallic colouring. The head is exserted and horizontal; the prothorax shining, constricted in front, and finely pitted. The elytra are brilliant metallic

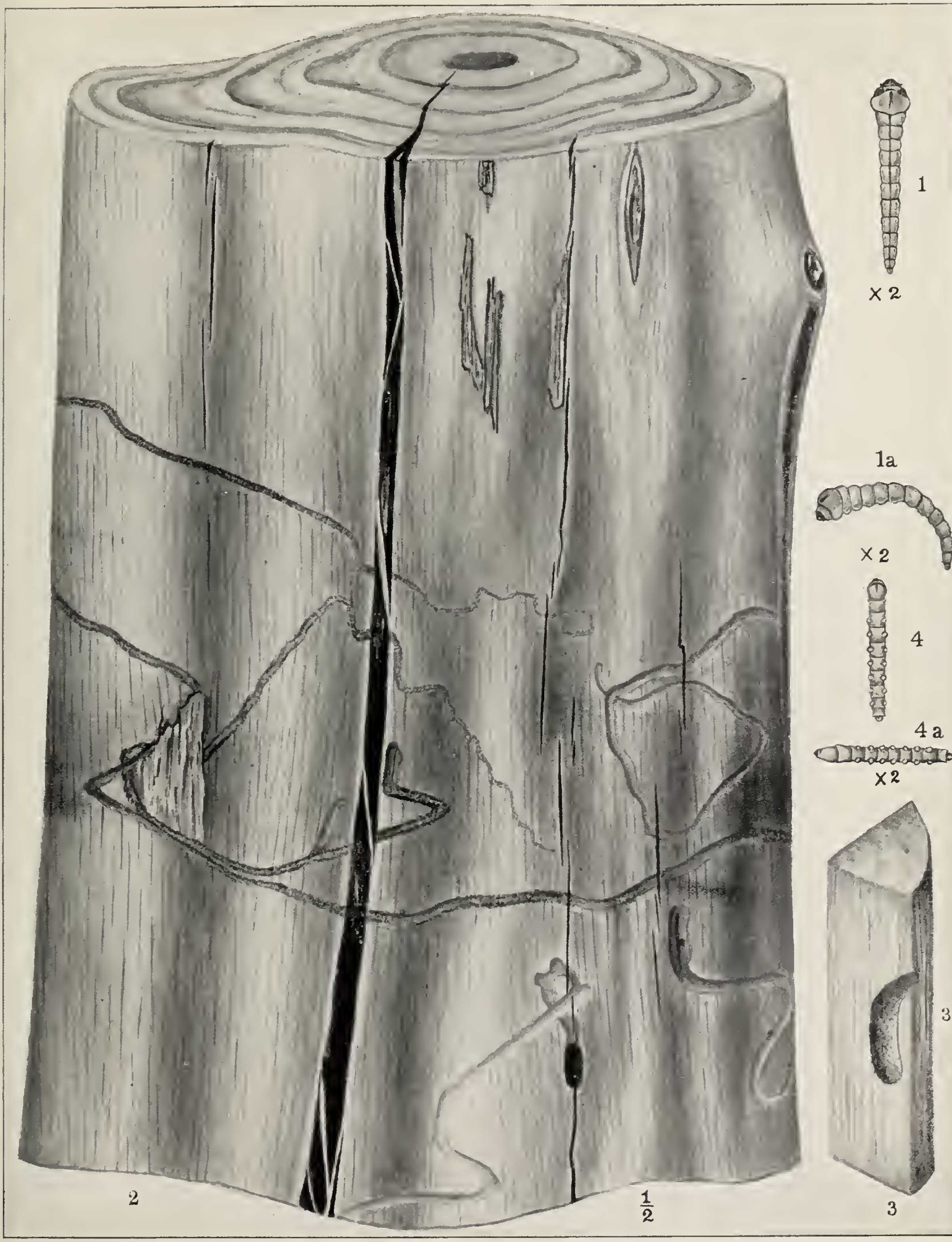
PLATE I.

FIG. 1, 1*a*, dorsal and side views of the larva of *Amorphosoma* sp.

FIG. 2. portion of an oak stem (half natural size) showing the larval galleries of *Amorphosoma* sp. in the sap wood.

FIG. 3, Entrance tunnel to pupal chamber and pupal chamber made by larva of *Amorphosoma* sp., in sap wood.

FIG. 4, 4*a*, dorsal and side views of grubs parasitic on *Amorphosoma* sp.



Half-tone. Survey of India Offices, Calcutta, 1909.

Amorphosoma ? sp.

[to face page 4.

green, constricted towards apex, the latter armed with several spines. Length 4 inch.

Life History.

Little is at present known on the life history of this insect. The larvæ eat out wide shallow irregular galleries and chambers in the bast layer of the tree, these galleries being out of all proportion to the width of the grub making them. At times they are long and wind irregularly about in an undecided fashion; at others the grub eats out a chamber or patch having irregular edges and no definite gallery or arms (Plate I, fig. 2). In all cases these galleries are made in fresh bast, the larva requiring sappy material for its food. The larval galleries or chambers are closely packed with wood excrement, the only free portion being the area occupied by the larva. They are roughly from 6 inches to 9 inches in length and $\frac{1}{4}$th inch to $\frac{1}{3}$rd inch in width. When full fed, the grub bores down into the sap wood at an angle; the tunnel so made is elliptical in section and of about $\frac{1}{2}''$ to $\frac{3}{4}''$ in length (fig. 3). At the end of this tunnel the larva eats out an oval elongate pupal chamber parallel to the long direction of the tree (fig. 3). In this chamber the grub then pupates. Both entrance tunnel in the wood and pupal chamber are quite free of wood excreta. The beetle on maturing crawls up the tunnel in the wood, bores through the bark of the tree, and escapes. The appearance of the irregular shallow larval gallery in the wood with the elliptical entrance holes down into the sap wood starting from near the larger end of the larval gallery are very characteristic of this beetle and are easily recognizable (*cf.* figs. 2, 3).

Damage committed in the Forest.

The buprestid evidently accompanies the more dangerous Scolytid bark borer *Dryocœtes Hewetti* and the longicorn *Xylotrechus* in attacking trees as soon as they are weakened by the *Loranthus* parasite, *Loranthus vestitus,* which infests them. Also old dying trees are evidently sought out by this insect for egg-laying purposes. In a tree of this nature newly dead the galleries of the beetle were very numerous, the beetle having evidently accelerated its death.

As has been often evidenced in Europe, small buprestid pests of this kind are quite capable of killing trees by themselves without any extraneous aid.

Natural Enemies.

I took from pupal galleries in the trees containing living grubs the elongate maggot-like grub shown in Plate I, figs. 4 and 4*a*.

This grub had all the appearance of being parasitic upon the bupres-tid one.

Points in the Life History requiring farther observations.

1. The time taken by the larvæ to reach full size.

2. The time or times, if more than one generation in the year, of appearance of the beetle.

3. The number of generations in the year.

4. In what stage of its metamorphosis the beetle hibernates through the winter.

Half-tone.

Survey of India Offices, Calcutta, 1909.

Lophosternus Hugelii.

[to face page 7.

PLATE II.

FIG. 1, larva—dorsal view—of *Lophosternus hugelii.*

FIG. 2, Beetle do. do.

FIG. 3, Section of base of an oak stem (half natural size) with part of the bark removed showing the shallow gallery, A, made in the sap wood by the young larva; the deeper gallery B made as larva reaches full size and the entrance hole C of the tunnel made down into the sap wood to pupate.

PART II: THE LONGICORN (CERAMBYCIDÆ) BEETLES OF THE OAKS.

LOPHOSTERNUS HUGELII, Redtenb.

The Oak Timber Longicorn borer.

Reference.—Gahan, Fauna British India, Coleop. Vol. I., Cerambycidæ No. 8 (p. 11)

Nature of Attack.

The grub eats out a deep and large irregular patch in the bast and sap wood of the Ban oak tree. When full fed it bores down into the heart of the tree.

Previous Record of Insect.

This beetle is common in the North-West Himalayan oak forests. I can find no data of its life history having been previously recorded.

Distribution.

Apparently spread throughout the oak forests of the Western Himalayas.

General Appearance.

Larva.—A large yellowish white elongate thick grub. Plate II, fig. 1.

Pupa.—Yellowish, white, stout with the general appearance of the beetle, the parts such as antennæ, wings, legs, etc., being free.

Beetle.—♂.—Chestnut red in colour, the head and prothorax darker than elytra, at times the thorax being mostly black. Head closely punctured; the last joint of the palpi distinctly widened towards the extremity. Eyes are large and are placed rather close to the insertion of antenna behind. Antennæ a little shorter than body, the first joint not reaching beyond the hind margin of the eye, 3 to 10 joints acutely produced at the apex on the anterior side. The prothorax is finely and closely punctured in front and along sides, smooth and shining medianly, the hind angles obtuse and projecting and the side margins produced outwards into two sharp points; elytra rugulose the ridges finely punctured and each with two or three weak raised costæ. The hind breast beneath covered with a tawny-coloured silky pubescence.

The last ventral segment is sinuate at the apex.

♀.—The antennæ hardly reach to middle of elytra and are more slender than in male. Hind breast with no tawny pubescence. Last ventral segment with rounded hind margin. (*Descr. after Gahan*). Plate II, fig. 2, shows this insect.

Life History.

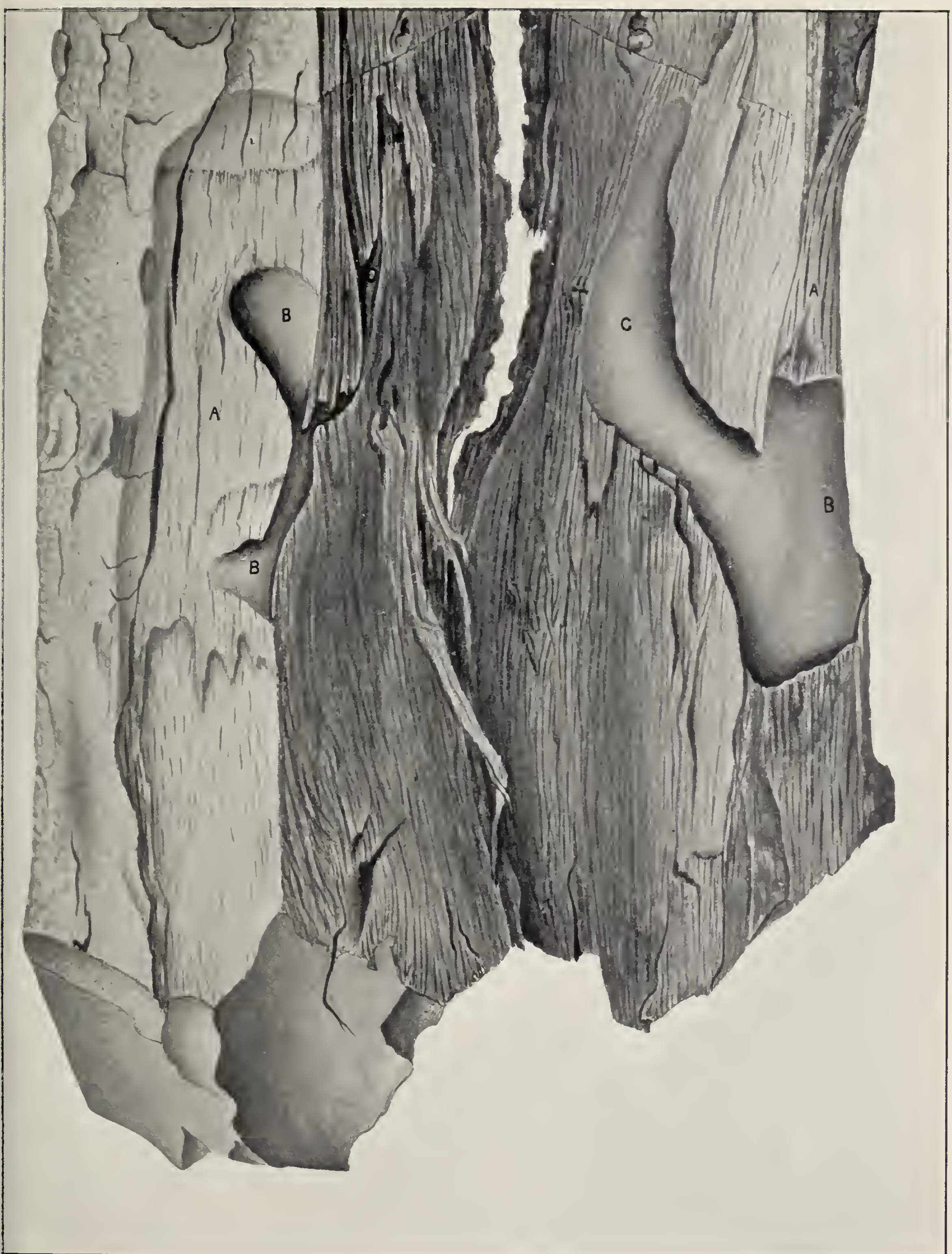
The egg is laid in an interstice in the bark, and the small grub on hatching out bores down to the bast and sap wood and feeds in this. At first whilst small the bast wood is only slightly grooved, Plate II, fig. 3A and Pl. IIIA, but as the grub becomes larger and its mandibles stouter it works down deep into the sap wood filling the whole of the gallery and depression thus made between the outer shell of the bark and the inner layer of sap wood with wood particles and excreta, Plate II, fig. 3B ; Plate IIIB. The irregular shaped area thus eaten out in the bast may be as much as 5″ across, the edges being very irregular and may stretch a fifth or a fourth round the tree, the height diameter being 4″ or more (Plate II, fig. 3 ; Plate III). When full fed, the grub, starting usually from one of the lower edges of the depression Pt. II, fig. 3C, tunnels into the wood to pupate. This tunnel is carried deep down into the wood and usually curves upwards from its orifice in the outer sap wood; the chamber bored out at the end of the tunnel is parallel to the long axis of the tree and is of larger diameter than the tunnel leading to it, Plate II, fig. 3C ; Plate IIIC. In making this tunnel and chamber the larva ejects every particle of wood eaten away through a hole which it cuts in the bark of the tree, and it is these holes and the heaped up wood dust and excreta to be seen at the foot of the tree which renders it easy to recognize and find this insect when it is in its full grown larval stage, although externally no trace of the large eaten out depression in the cambium layer and sap wood will be visible on the bark of the tree. Beyond this fact that the larva is full grown and is pupating in its pupal chamber at the commencement of June, and that the beetle issues during the rains (July-August), nothing further on the subject of its life history is known.

Damage committed in the Forest.

This insect, when at all abundant in the forest, is a dangerous pest owing to the fact that its method of feeding is capable of destroying the tree, whilst its mode of pupation destroys the timber. The large circular holes and borings in oak timber are well known in the Western Himalayas and are entirely the result of the work of this beetle.

PLATE III.

Section of base of an oak stem split open to show the pupal chamber, C, of the longicorn beetle *Lophosternus hugelii* in the interior of the tree. A, Shallow gallery in sap wood made by young grub; B, deeper gallery made in sap wood by nearly full grown larva; C, the pupal chamber in heart wood of the tree.



Half-tone, Survey of India Offices, Calcutta, 1909

Attacks of *Lophosternus Hugelii* in Oak.

[*to face page 8.*

As far as I am aware, the fact that its larva, whilst attaining to full growth, destroys so much of the bast layer has never been previously recorded, and a complete study of its life history by those in a position to do so is urgently needed.

Points in the Life History requiring further observations.

1. When the eggs are laid.
2. How long the larva spends in this stage of its metamorphosis feeding in the bast layer and sap wood.
3. When the larva first commences to bore into the heart wood of the tree, and how long this tunnel and the pupating chamber take to make.
4. Where the larva passes the winter.

XYLOTRECHUS STEBBINGI, Gahan.

Reference.—Gahan, Fauna British India, Coleop. Vol. I, Cerambycidæ No. 274 (p. 244).

Nature of Attack.

The eggs are laid by the beetle on the bark of living or newly felled *Moru* oak trees. The grubs on hatching out feed entirely in the bast and sap wood until full grown, eating out winding galleries.

They then bore down into the inner sap wood, eat out a pupal chamber, and pupate in it.

Previous Record of Insect.

This insect was taken by myself in oak in Bashahr State, North-Western Himalaya, in 1901.

It was sent to the British Museum where Mr. Gahan, the well-known authority on the family, determined it as an unrecorded species. It is also an inhabitant of Tibet.

Distribution.

The insect is recorded from Bashahr State in the North-Western Himalayas and Tibet. Probably spread throughout the *Moru* oak belt in the Western Himalaya.

Description.

Larva.—Whitish yellow, elongate, the segments of the body more or less of the same size decreasing gradually posteriorly. No enormously large segment follows the head as in the case of the buprestid larva. Head black. Length about 1" when full grown. See Plate IV, figs. 1, 1*a*.

Beetle.—Brown : head and prothorax clothed with a greyish pubescence, the prothorax with four small brown spots in a transverse row across the middle—two dorsal and two lateral. Elytra subglabrous, testaceous brown, narrowly covered with grey pubescence at the base, marked with some small spots of ashy-grey pubescence which form three interrupted bands—one near the base, another just before the middle, the third midway between it and the apex; the apex also narrowly bordered with ashy-grey. Body beneath covered with grey pubescence, a rather large posterior spot on each of the metathoracic episterna ashy-white. Antennæ less than half the length of body; third joint slightly longer than the first. Femora rather strongly thickened; the hind pair extending a little past the apex of the elytra. First joint of hind tarsi twice as long as the second and third united.

Length 12—18; breadth $3\frac{1}{2}$—5 millim. (*Descr. after Gahan*). Plate IV, figs. 2, 2*a* shows the beetle.

Life History.

The larva of this insect feeds entirely in the bast and outer sap wood of the *Moru* oak. I have not as yet taken it in the *Ban*. The grub grooves both bast and sap wood, eating out large irregular galleries in the long axis of the tree (Plate IV, fig. 3). Occasionally the gallery is quite straight, but it is more often irregular with winding edges; the larva however, appears to confine itself to the layer of wood between the long straight medullary rays and more especially so in its young state. The larval gallery is always tightly packed with the wood refuse and excreta ejected by the larva and is about 5" to 8" in length with an average breadth of $\frac{1}{5}$th inch. On becoming full grown the grub bores down into the sap wood at an angle for about $\frac{1}{2}$" to 1" and then eats out a pupal chamber parallel to the long axis of the tree (fig. 4). Both chamber and entrance gallery in the wood are kept quite free of wood dust and excreta. When mature the beetle crawls up the entrance

tunnel in the wood, bores through the bark which overlies it and leaves the tree.

Larvæ in various stages up to nearly full grown and full grown were taken from trees in Naini Tal towards the end of May. Several of these grubs had already bored down into sap wood and constructed the pupal chambers and commenced to pupate.

The beetle appears on the wing towards the end of July and in August, the pupal stage lasting from six weeks to two months. It is possible that there may be two generations of the insect in the year, but I think it is improbable. It is more likely that the beetles issue at intervals (as the larvæ mature) through a part of July, August and into September.

Damage committed in the Forest.

The insect attacks the tree in a manner very similar to its Buprestid companion above described. The two are not infrequently found at work in the same tree, the Scolytids being at times also present.

XYLOTRECHUS SMEI, Lep. et Gory.

Reference.—Steb. Departmental Notes on Insects that affect Forestry (X. vicinus). I, 24. Gahan, Fauna British India, Coleop. Vol. I, Cerambycidæ No. 270 (p. 241).

Nature of Attack.

Similar to that of *X. stebbingi*. Only as yet reported in the *Moru* oak.

Previous Record of Insect.

This insect was taken near Kilba in Bashahr in 1901 by the Range Officer in charge of the Range.

Distribution.

In addition to Bashahr State in the North-Western Himalayas, the insect according to Gahan is to be found in Bhutan and the Deccan.

B 2

Description.

Larva.—Resembles that of *X. stebbingi.*

Beetle.—Brown above; with a greyish or yellowish pubescence covering the head and most of the prothorax and forms bands and spots on the elytra placed as follows :—

(1) a transverse band on each at the base, followed a little behind by

(2) a short transverse spot;

(3) a narrow band which begins near the scutellum, passes close to the suture, diverges a little from it posteriorly and at a short distance before the middle curves outwards to the side, thence it bends forward a little before reaching the margin;

(4) a narrow, obliquely transverse somewhat wavy band, placed a little behind the middle;

(5) an apical band, which is slightly produced forwards at the suture. Body beneath marked with spots or bands of whitish pubescence.

Length 11—17; breadth 3—5 millim. (Descr. after Gahan). Plate IV, fig. 5, shows a dorsal view of this beetle. The beetle from which the drawing was made was much rubbed.

Life History.

Little is known on the subject of the life history of this beetle. It probably closely resembles that of *X. stebbingi.*

The larva tunnels in the bast and wood of the oak (*Quercus dilatata*) in Bashahr. Specimens of the mature beetle were taken from the trees in August 1903 and sent to me by the Range Officer of the Kilba Range. Beyond this nothing is known about the insect.

The damage done by it to the tree is probably the same as that already detailed for *X. stebbingi.*

Protection and Remedies against the Longicorn Borers.

Remedial measures in the forest for these longicorn beetle pests are somewhat difficult to prescribe as the insects are normally distributed throughout the area occupied by the tree. A point, however, which should always be borne in mind is that the egg is deposited by the beetles we have here considered on the bark of green standing sickly trees or newly felled ones, and that the young grub requires at first the soft bast layer to

PLATE IV.

Fig. 1 1*a*, side and dorsal view of the larva of *Xylotrechus Stebbingi.*

Fig. 2, 2*a*, side and dorsal views of the beetle *Xylotrechus Stebbingi.*

Fig. 3, Section of stem of an oak with bark removed showing the larval galleries of *X. Stebbingi* in the sap wood.

Fig. 4, Section of portion of stem showing the elongate pupating chamber of *X. Stebbingi* in the wood.

Fig. 5, beetle of *Xylotrechus Smei.*

Half-tone.

Survey of India Offices Calcutta, 1909.

Xylotrechus Stebbingi, Gahan. Xylotrechus Smei, Lep. et Gor.

[to face page 12.

feed upon. Consequently barking the trees soon after felling will ensure the destruction of the *Xylotrechus* beetles since their grubs spend the whole of the period of their existence in this stage in the bast layer and outer sap wood. The barking of the trees leads to the drying up of the bark and the death of the grubs. To make certain of protecting oak timber against the attacks of the oak timber longicorn borer it is absolutely essential that the tree should be barked as early as possible after felling in order to ensure that the grub does not get down into the sap wood to such a depth that the barking of the tree would have no harmful effects on it. Once it has got there the barking of the tree will not prevent the larva from making its destructive galleries in the heart wood of the tree and thus ruining the timber.

Points in the Life Histories of the Xylotrechus Beetles requiring further observations.

1. Where and when the eggs are laid. Is it on the bark in July, August ?
2. How long the larva spends in the larval stage.
3. Length of the pupal stage.
4. The number of generations in the year.

Part III: THE SCOLYTID (SCOLYTIDÆ) AND PLATYPID (PLATYPIDÆ) BARK AND WOOD BEETLES.

As far as present observations have led, four, and perhap a fifth, Scolytid and Platypid insects are known to infest the oaks. Two new bark boring beetles *Dryocœtes Hewetti*, n. sp. and *Sphaerotrypes querci*, n. sp., and the wood borers *Chramesus globulus*, n. sp., *Diapus impressus* and *D.* sp. prox *impressus.*

THE BARK BORERS.

DRYOCŒTES HEWETTI, Steb.

Reference.—Stebbing. On "Some undescribed Scolytidæ of Economic importance from the Indian Region," Indian Forest Memoirs, Zoology Series, Vol. I, Pt. i (p. 11.)

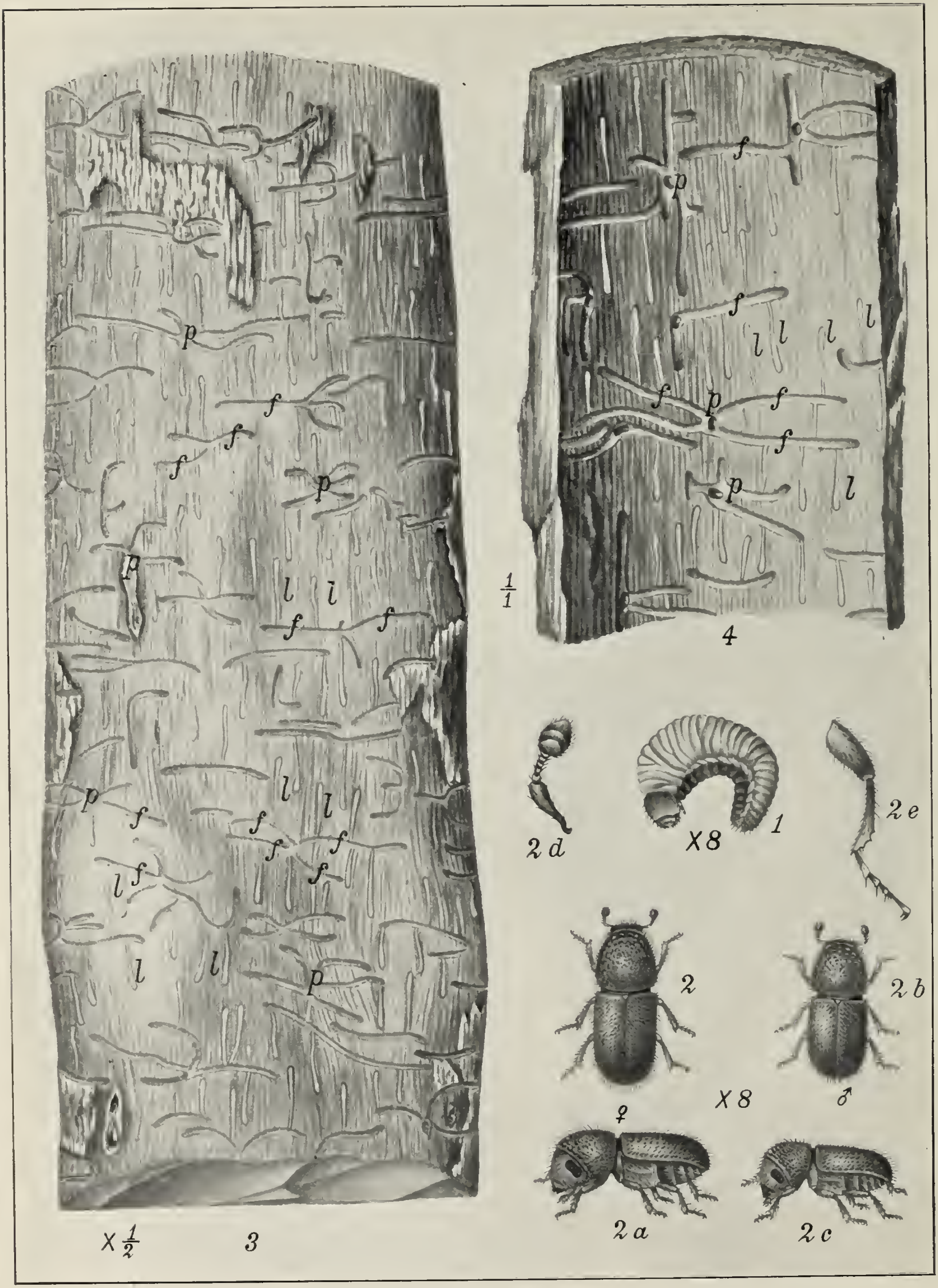
Nature of Attack.

The male beetle bores through the bark of the tree and eats out a pairing chamber, squarish in shape, in the bast and sap wood. Three or four female beetles successively enter the pairing chamber through the male entrance hole (the first one enlarging the entrance gallery in doing so) and after pairing with the male bore galleries away from the pairing chamber. These galleries are eaten out in a direction at *right angles* to the long axis of the tree (in standing trees) and typically two females bore in one direction and the other two in the opposite one, each female or egg gallery being distinct from the other; the eggs are deposited on either side of these egg galleries and the larvæ on hatching out bore away in a direction at right angles to the egg gallery, the larval galleries being straight.

When sufficiently numerous, the beetles and their larvæ remove all the cambium or bast layer of the tree and the tree dies.

Previous Record of Insect.

I have no previous record of this insect.



Half-tone

Survey of India Offices, Calcutta, 1909.

Dryocœtes Hewetti, Steb.

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PLATE V.

FIG. 1, larva of *Dryocœtes Hewetti*, Steb.

FIG. 2, 2*a*, dorsal and side view of female, 2*b*, 2*c*, same of male beetle of *Dryocœtes Hewetti*; 2*d*, enlarged antenna, 2*e*, enlarged leg of same.

FIG. 3, Section of stem of oak showing the pairing chambers, and egg and larval galleries of Dryocœtes Hewetti in the outer sap wood. p. pairing chamber ; *f*. female or egg gallery ; *l*. larval gallery. (half natural size.)

FIG. 4, same in bark, natural size.

Distribution.

At present I have only records of this insect from the Naini Tal and Kumaun oak forests in the North-Western Himalaya.

General Appearance.

Larva or *Grub.*—A small white elongate worm with a yellowish head. The grub instead of being curved as is usual with bark boring Scolytid grubs is more or less straight and tapers slightly posteriorly. Plate V, fig. 1, shows the larva.

Pupa.—Whitish yellow with ordinary beetle shape.

Beetle.—A small oblong black insect with a reddish chestnut tinge. Head with front slightly convex, shining, punctate, very finely transversely striate at sides with long scattered hairs on front and a fringe of hairs on mouth. Prothorax slightly broader than long, base truncate, humeral angles rounded, sides and apex forming a blunt ellipse ; surfaee convex, raised into a point medianly and depressed posteriorly ; granulose, the granulations coarse on anterior half especially on disk and much finer posteriorly. Scutellum rather large, shining, convex, rounded. Elytra slightly broader apieally than prothorax and a fourth as long again ; truncate at base, apex strongly rounded ; surfaee shining, flat medianly and strongly deelivous apically, the declivity shining and edged with long spiny hairs ; rest of surface with rows of punctures which are fine basally and medianly and confluent and rugose medianly. Under surface lighter reddish brown medianly with longish hairs dense laterally. Length 2·5 —3 millim.

Plate V, figs. 2, *2a* show the dorsal and side views of the female beetle ; *2b*, *2c* the same of the male beetle ; *2d* shows the antennæ enlarged ; and *2e* a leg.

Life History.

The following notes on the life history are eompiled from observations made in the field during the latter half of May and the first half of June. The life history of the insect for the remainder of the year is at present unknown.

The male inseet flies to and settles on the outer bark of the tree and then bores into the bark eating out a straight tunnel, of the same diameter as itself, down to the bast layer and sap wood of the tree. On reaching the latter it gnaws out a small chamber which grooves both the bast and sap wood and is squarish in appearance (Plate V, figs. *3p*, *4p*).

When this work is complete, or before the male has finished the pairing chamber, a female enters the orifice of the entrance tunnel of the male in the bark and works her way downwards, enlarging the tunnel as she goes in (as she is larger in circumference than the male), till she reaches the male in the pairing chamber. After pairing with the male the female commences to eat out a gallery in the sap wood and bast; this gallery takes a direction away from the pairing chamber and is always more or less at right angles to the long axis of the tree (figs 3*f*, 4*f*), in this differing from other Indian coniferous and broad-leaved Scolytidæ,* in which the gallery bored by the female is parallel to the long axis of the tree. As she eats out this tunnel, the female makes little indentations in the edges on both sides and places an egg in each. When she has completed the gallery, which is the egg gallery, *i.e.*, when she has laid all her eggs, she dies *in situ* at the head of the gallery. Before the gallery is completed, however, the larvæ from the first laid eggs commence to hatch out. The larva eats out a narrow tunnel in a direction at right angles from the egg gallery (*cf.* figs. 3*l*, 4*l*), and this larval gallery appears to be invariably straight. This may be due to the hard straight fibres of the oak wood, but whatever the cause, this habit of the grub distinguishes it at once from other known Indian Scolytid bark boring grubs whose tunnels invariably serpentine; also, owing to the fact that the egg galleries are at right angles to the long axis of the tree *i.e.*, go round the tree, the larval galleries go straight up and down the tree. The plan thus made is so different to any of the at present known Indian Scolytidæ as to render the presence of this insect in the trees easily recognizable.

The larval galleries increase in diameter with the growth of the grub as it eats away from the egg gallery; they do not groove the sap wood as deeply as the female ones do.

The larva where full grown eats out a depression in the sap wood at the end of its gallery and pupates. On maturing from the pupal stage the beetle eats its way through the bark which covers it, making a small circular exit tunnel in it and escapes to seek out a good tree in which to oviposit and carry on the attack. The presence of these numerous exit holes on the outside of the bark serves as an indication that the beetles bred in it have left the tree.

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* *Sphaerotrypes siwalikensis, Scolytus major, Polygraphus major, etc.*

The pupating chamber is $\frac{1}{5}$th inch by $\frac{1}{7}$th inch in size ; the egg gallery from $1\frac{1}{2}$ inches to 2 inches in length and those of the larvæ from $1\frac{1}{4}$ inches to $2\frac{1}{4}$ inches ; the number of eggs laid is usually about 20.

This insect is a polygamous one, and the male pairs with three or four females. In the case of the latter typically the egg galleries of two of the females are taken in one direction and those of the other two in an opposite one, alternate beetles boring in opposite directions after pairing. A plan similar to that shown in Plate V, figs. 3 and 4 is thus obtained. Practically, however, it will be found that the direction of these egg galleries, varies and they may curve considerably ; at times even it will be found that three take off on one side and one only on the other ; or again one or two may be extremely long and a third very short, the fourth being absent. These variations are doubtless due to differences in the physical capabilities of the beetles themselves and to variableness in the hardness of the wood, such as knots, etc. After pairing with the females the male dies in the pairing chamber.

This beetle is an active little insect leaving the trees in daylight, which is most unusual with *Scolytidæ,* and walking and flying actively about in the sunlight.

From observations made towards the latter part of May it is evident that a generation of the beetle was just maturing and issuing from the trees at this period of the year. This generation of the beetles is probably the first generation of the year, and it is certainly followed by a second, since larvæ from eggs laid by it were taken from the trees in June. It is probable that there is at least a third generation of beetles during the year, from eggs laid by the second generation which probably issues some time in August. This point, however, requires further careful observations to be carried out between July and the close of the year. The eggs of the May generation of the beetle are probably laid in the trees early in April by beetles which have either hibernated through the winter in the tree or which have passed the winter as larvæ in the larval galleries in the bast, subsequently maturing and issuing as beetles as soon as the first warmth of spring makes itself felt.

Damage committed in the Forest.

At present I have only taken this insect in full-grown and old oak trees, but it apparently attacks both the *Moru* and Ban oaks. The danger

to be feared from the insect is due to its habit of ovipositing in the bast layer of the trees. As has been shown, the operations of the beetles and their larvæ lead to the destruction and disappearance of the bast, and when the insects are numerous end in the death of the tree. In several instances the death of large trees examined appeared to be due directly to the attacks of this insect.

Its greatest danger is, however, evidently to be found in the fact that it forms such a powerful ally to the Loranthus parasite which infests the oaks. Broad-leaved trees are much more resistant to the bark boring beetle attacks than is the case with conifers, and consequently it is probable that the oak can ordinarily hold its own against the Scolytid.

It is essential to the latter that the bast layer of the tree should be fresh and sappy, but the beetle invariably seeks out diseased trees or those which have become weakened through some cause in which to lay its eggs. The slow strangulation and consequent weakness set up in the trees by the Loranthus parasite places the tree in the exact condition preferred by bark beetles, and where these insects are at all numerous an attack in Loranthus-weakened trees may be looked upon as a foregone certainty. Once the insects have obtained a hold in a forest their powers of rapid multiplication render them a pest which has to be reckoned with.

Protection and Remedial Measures.

Protective and remedial measures for safeguarding the uninfested trees in Naini Tal and elsewhere have already been considered in the section devoted to the longicorn beetles. It will be well, however, to glance at measures applicable to this insect alone, since it is probable that very often it infests the tree before the Buprestid or Cerambycid pests make their appearance.

To combat these bark borer pests adequately it becomes necessary to know the exact life history of the insect, and more especially in what months during the year it is in its larval stage, for it is in this stage that it can be best attacked. When the tree is full of nearly full-grown larvæ, it should be felled and barked and the bark burnt. From the life history as at present observed we know that this can be done at the end of the first week in May for the grubs of the first generation and at about the end of June for those of the second generation.

Further, both as a means of discovering the number of insects in a forest and as a means of protecting that forest as well, 'trap trees' should be arranged for. Trees which are either sickly, already attacked, or are chosen for other reasons, should be selected and girdled or felled a week or so before the flight time of the beetles. The insects will resort to these to oviposit, and when egg laying has been completed and the trees are full of nearly full-grown larvæ, the bark should be stripped off and burnt.

Points in the Life History requiring further observations.

1. Where and in what stages of its metamorphosis the insect hibernates through the winter.

2. The times of appearance throughout the year of the insect as—
   (*a*) full-grown larvæ.
   (*b*) mature beetles on wing.

3. The number of generations passed through during the year.

SPHAEROTRYPES QUERCI, Steb.

Reference—Stebbing, On "Some undescribed Scolytidæ of Economic Importance from the Indian Region," Indian Forest Memoirs, For. Zool. I, Pt. I, (p. 5).

Nature of Attack.

The female beetle eats out an egg gallery in the bast and sap wood of the tree, laying eggs in indentations on either side The larvæ on hatching out mine out galleries in the bast in directions at right angles (about middle of egg gallery) or which trend upwards or downwards in the upper and lower parts of the egg gallery (*cf.* Pl. VI, fig. 3).

When numerous, the bast layer is entirely destroyed and the tree attacked dies.

Previous Record of Insect.

I have no previous record of this insect having been taken or described. I only took specimens of the beetle in two *Moru* oak trees in the grounds of Government House, Naini Tal, and then only sparingly. Larvæ were taken in one of the trees.

The genus contains two species which commit serious damage to sâl trees in the United Provinces and in Assam and a third, which may be identical with one or other of these in the Central Provinces sâl forests.

Distribution.

Naini Tal Oak Forests, N.-W. Himalaya (as at present known).

Description.

Larva.—Small white oval. Very convex above and much corrugated and channelled (Pl. VI, fig. 1).

Beetle.—Short, oval, very convex. Black with antennæ slightly lighter and tarsi ferruginous.

Head punctate, more strongly so at sides, hairy at vertex. Prothorax $1\frac{1}{2}$ times as broad as long, base bordered and produced backward to form an obtuse angle, the angle truncate, concave on either side, emarginate anteriorly and sides rounded and narrowed anteriorly, a narrow elevated line down centre more prominent and shining at base and not reaching to anterior margin; coarsely and somewhat closely rugose; a few stout bristles, yellow in colour, on anterior outer margin. Scutellum squarish, oblong, punctate. Elytra slightly wider than thorax, not quite twice as long as latter, conjointly emarginate at base, basal borders crenate, basal angles strongly rounded and sides rounded from base to apex. Almost black with a dull reddish tinge on them; striate, the striæ deep and prominent, but not reaching to base of elytra, shining, flat with scattered punctures, the interstices slightly elevate and convex, coarsely rugose punctate. Under surface black, with a scattered yellow pubescence, abdominal segments 1 and 5 large and equal to one another, 2, 3 and 4 much narrower, punctate with sparse yellow hairs on them. Long 3 millim. (Figs. 2, 2*a*, Pl. VI, show a dorsal and side view of this beetle.)

Life History.

Very little is known upon the subject of the life history of this bark borer. Nearly full-grown larvæ were found in their galleries in the tree towards the end of May, these being the larvæ of the first generation of the year. The beetles mature about 1st to 2nd week in June. We have yet to discover how many generations of the insect there are in the year. In the case of its sâl tree confrère in the Dun four, and a partial fifth, generations are passed through, and it is probable that the oak species has at least three life cycles in a season. It is important that this fact should be definitely and accurately determined. Fig. 3 shows the diagram of the egg and larval tunnels made in the sapwood and bast by this insect.

The damage it is capable of committing to the tree and the forest and the methods of combating its attacks are similar to those detailed above for the *Dryocœtes* bark borer.

THE WOOD BORERS.

CHRAMESUS GLOBULUS, n. sp.

Reference.—Steb. Departmental Notes on Insects that affect Forestry (Chramesus ? sp.), I, 409.

Nature of Attack.

The beetle tunnels down into the heart wood of the Ban oak to lay its eggs. Only green trees are attacked, usually sickly standing ones or newly felled ones. The damage committed is to the timber only.

Previous Record of Insect.

I first took this beetle early in May 1901 in Jaunsar, N.-W. Himalaya. I have seen no other record of it either before or since.

Distribution.

The *Ban* oak forests of the N.-W. Himalaya.
Elevation roughly about 5,000 feet to 5,500 feet.

Description.

Beetle.—Small, globular, very convex above, flat beneath, widest across middle. Head small, black with a yellowish brush of hair on forehead. Prothorax black, pentangular in shape, anterior margin straight, slightly ridged with a transverse depression behind the ridge, posterior margin produced back into a median point. Elytra very convex, purplish or black in colour, striate, base rugose, the interstrial spaces with series of fine raised points ; the striæ curve inwards towards apex ; surface set with a short yellowish pubescence. Under surface flat, black ; abdominal

segments clothed with a short spiny yellow pubescence, denser laterally. Length, 3 millim. (Pl. VI, figs. 4, 4*a* show a dorsal and side view of this beetle.)

Life History.

The beetle first appears on the wing in the spring about the first week in May at elevations of 5,000 to 5,500 feet.

It tunnels into the wood of newly dead or dying *Ban* oaks for egg laying purposes. The insect bores straight through the bark and into the sap wood and then turns to one side or the other and carries its gallery right down into the heart wood at an angle. These beetles lay the eggs of the first generation of the year.

This is all that is at present known on the life history of this beetle. It will not attack dry wood. The holes drilled in the wood are circular in section.

DIAPUS IMPRESSUS, Janson.

Reference.—Steb. Departmental Notes on Insects that affect Forestry, I, 414.

Nature of Attack.

This insect, as also its companion Platypid, *D.* sp. prox *impressus*, bores down into the timber of green standing or felled green oak trees and lays its eggs at the bottom of the tunnel so bored in the heart wood.

Previous Record of Insect.

The insect was first reported as riddling *Ban* oak stumps at Deoban, N.-W. Himalaya, 9,000 feet, as long ago as the year 1891.

Distribution.

Jaunsar, N.-W. Himalaya.

Description.

Larva.—White, legless, straight with a light orange yellow head and black mandibles.

Beetle.—Elongate cylindrical with a vertical exserted head, broader than thorax, and weak legs. Red brown, shining, basal margin of the

PLATE VI.

Fig. 1, larva of *Sphærotrypes querci, Steb.*

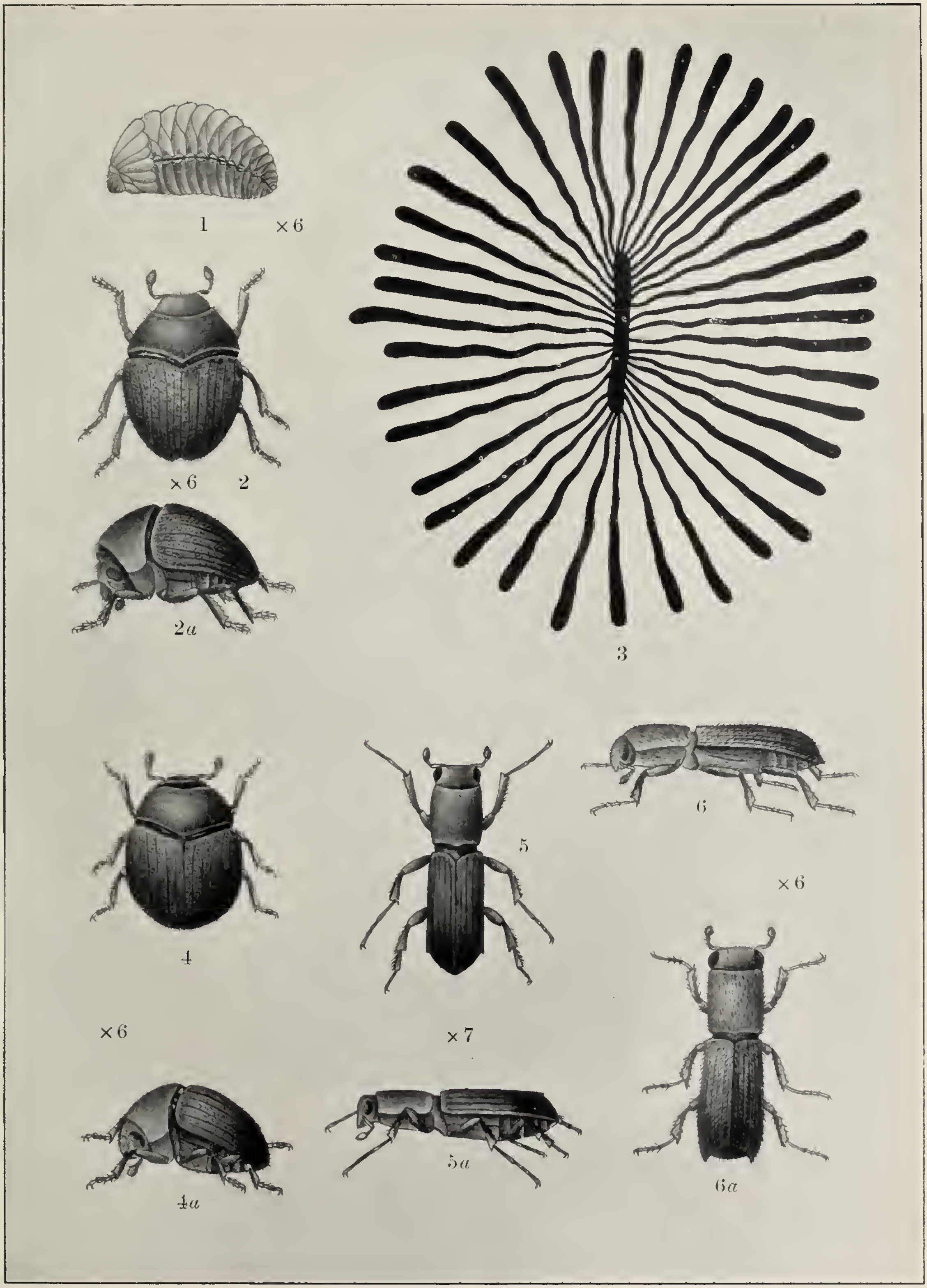
Fig. 2, 2*a*, dorsal and side view of beetle *Sphærotrypes querci.*

Fig. 3, Diagram showing egg and larval galleries of *Sphærotrypes querci.*

Fig. 4, 4*a*, dorsal and side view of *Chramesus globulus* n. sp.

Fig. 5, 5*a*, do. do. do. *Diapus impressus.*

Fig. 6, 6*a*, do. do. do. *Diapus* sp. prox *impressus.*



Half-tone Offices, Calcutta, 1909

Sphærotrypes querci, Steb. Diapus impressus Janson.

Chramesus globulus, n. sp. Diapus sp. prox. impressus.

[to face page 22.

thorax and elytra brownish yellow, apical posterior of the latter red brown; legs and antennæ pale yellow. Thorax oblong, strongly emarginate at sides before the middle, base finely and closely punctured and with a slight median line. Elytra punctate striate, the second striæ from suture and the outer marginal one broader and more strongly punctured, the first and second interstices from the suture strongly raised, the fourth slightly convex; the apex coarsely punctured, subtruncate and unarmed in the male, in the female with five acute apical spines. Under surface light orange yellow between the second and third pairs of legs, brown anteriorly to this, and dark brown to black on abdominal segments which are very short. Abdomen densely pubescent at apex in male, in the female concave, rugulose. Long $3\frac{1}{2}$ to 4 millim. (Pl. VI, figs. 5, 5*a*.)

Life History.

The only specimens of this insect taken appear to have been sent to the Indian Museum, Calcutta, from Deoban, Jaunsar, in 1891. The insects were reported as tunnelling into *Ban* oak stumps, but nothing further appears to be known about them.

DIAPUS sp. prox. IMPRESSUS.

Reference.—Steb. Departmental Notes, I, 415.

Nature of Attack.

Similar to that of *D. impressus.*

Previous Record of Insect.

Specimens of this beetle were first taken by the writer in June 1902 in Jaunsar, N.-W. Himalaya.

Distribution.

Probably throughout the Quercus incana forests of the N.-W. Himalaya.

Description.

The beetle resembles *Diapus impressus* but is much larger being 5—5·4 millim. in length. The colour is darker red, the thorax being entirely of this colour, as are the legs with the exception of the tarsi which are

lighter brown. The front of the head is only very finely pitted in the male, but strongly punctured in the female. The thorax is strongly constricted at the sides behind the middle and has no median line. The apical margin of elytra is concave in male and in female truncate, with the outer edges produced into teeth curving inwards. The abdomen is concave behind in the female. Figs. 6, 6*a*, Plate VI, show this beetle side and dorsal view.

Life History.

The insect is to be found on the wing at the commencement of June at elevations of 6,000 feet. It tunnels into the *Ban* oak for egg laying purposes. The beetle appears to prefer trees which are dead but not yet absolutely dry, and it bores down through the thickest bark into the heart wood making circular tunnels, the sawdust eaten out being ejected at the surface of the entrance hole. A tree attacked can be easily detected by the presence of these small heaps of sawdust piled up on the outside bark. The tunnels may be quite straight or curved slightly. Both male and female beetles are to be found in the tunnel and pairing probably takes place inside. The female insect appears to live for some time after egg laying is completed, finally dying in the mouth of the tunnel and so blocking it to predaceous enemies The eggs are laid at the bottom of the tunnel and the larvæ feed on fungus growths with which the walls of the tunnel are discoloured. The tunnels are as much as 9—12 inches in length.

This is all that is at present known about the life history of this insect.

Damage committed in Forest by the Wood Borers.

As will be seen from the little at present known about the life histories of these three wood borers, the damage they commit is entirely to the timber of the tree since the small portion of bast they eat through on their way to the heart wood is a negligible quantity. When plentiful the beetles entirely ruin the wood of a tree for timber purposes and greatly reduce the value of fuel stacks.

Protection and Remedies.

When wood is badly attacked by these wood boring beetles, the only safe method of destroying them and endeavouring to lessen their numbers in an area is to burn the whole of the infested timber and fuel. The

actual hole or tunnel in the wood made by these small Scolytid wood borers is of small diameter and therefore in itself of no great consequence. When, however, the insect appears in numbers, the timber is so riddled as to be quite useless for timber purposes. Its value as firewood is also greatly lessened owing to the great loss of weight the attack results in. It is one of these wood borers which occasionally causes great loss of beer from beer casks in India, and since the Hill Breweries in N.-W. India make use of oak timber to a great extent it becomes of the first importance to have a working acquaintance with the wood borers of the tree.

Points in the Life Histories requiring further observations.

We know nothing about the life histories of these wood borers save that the first generation of the beetles lays eggs in the trees some time in May.

(2) We require to know how long the larvæ spend in this stage of their existence.

(3) When the second generation of beetles appears.

(4) Whether there are more than two generations in a year.

(5) Also in what stage the insects pass through the winter, and whether the beetles are abundant in the oak forests of the Western Himalaya.

PART IV: THE SCALE INSECT OF THE OAK.

KERMES HIMALAYENSIS, Green.

(The *Ban* Oak Grey Scale.)

Reference.—Green, Ent. Monthly Mag. 1908.

Nature of Attack.

This scale insect thickly encrusts the branches, twigs, leaf stalks, leaves, and buds of the *Ban* oak, sucking out the sap and finally, when abundant, killing the tree.

Previous Records of the Insect.

I have no previous record of this pest and at the time of its discovery was of the opinion that it had never been previously recorded in this connection.

This surmise was corroborated by Mr. Ernest Green, Government Entomologist, Ceylon, the well-known expert on this family. The genus is known to infest oaks in Europe and North America. In the Catalogue of the Coccidæ of the World* Fernald gives a list of 28 species of this genus, all of which, with the exception of one living on an Acacia, infest species of European and North American oak. This fact adds peculiar interest to the discovery of the genus in India on one of the Himalayan oaks.

Distribution.

At present the insect has only been reported from the *Ban* oak forest on the hills to the north of Bhim Tal in the Almora District in the N.-W. Himalaya.

Description.

Eggs.—Elongate, tiny, white, with a white filamentous papery shell covering; enclosed in considerable numbers beneath the dome-shaped scale, forming a fine white mass of elongate bodies (*vide* Plate VII, fig. 1).

Newly hatched small scale.—Very small, reddish brown in colour, consisting of a head and 12 segments. The antennæ are short and small and there are a pair of long anal appendages (fig. 2).

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* A Catalogue of the Coccidæ of the World by M. E. Fernald, Bulletin No. 88, Hatch Experimental Station of the Massachusetts Agricultural College.

PLATE VII.

Fig. 1, eggs of *Kermes himalayensis*, Green.

Fig. 2, young newly hatched larva of *Kermes himalayensis*.

Fig. 3, adult female viewed from behind (after Green).

Fig. 4, antenna of adult female ×450 (after Green).

Fig. 5, young insect with the scale partially formed round it.

Fig. 6, branch of oak with young immature scales to be seen in considerable number on the outer bark.

Half-tone.

Survey of India Offices, Calcutta, 1909

Kermes Himalayensis, Green.

[to face page 26

Young female scale.—Small flat elongate elliptical with blunt ends, the posterior extremity broadly rounded; segmented with ridged tuberculate reddish grey smoke-coloured segments and from 1—8 to 1—12 inches in length. They have no scale covering and are almost indistinguishable from bark colouring (*vide* Plate VII, fig. 6).

Fig. 5 shows a more developed scale with the covering partially formed round it on outer edges.

Old female insect.—Black, shining with white streaks and specks on it giving the scale a mottled grey appearance.

Spherical or spherical-elliptical in shape, very convex above and flat beneath with a long diameter of $\frac{1}{4}$ inch and a transverse one slightly less; the shape often disguised by crowding. Skin smooth, shining, milky white or reddish, marbled and spotted, the markings black, punctate (see Plate VII, fig. 3; Plate VIII, figs. 1, 2). Antennæ short two jointed with 4 short hairs (fig. 4).

The scale when full grown greatly resembles at a little distance the pupæ of the predaceous coccinellid (lady bird) beetle *Vedalia guerini* which is predaceous upon the sâl monophlebus scale insect.

Life History.

On the 12th June 1908 this scale was discovered infesting the branches and crowns of the *Ban* oak forest which clothes the hills to the north of Bhim Tal. Mr. Milward, I.F.S., in charge of the Naini Tal Division, has since reported it to be in considerable abundance in the oak forest on the Naini Tal-Bhawali Road.

I am given to understand that the recent long drought has unfavourably affected the oaks here and there throughout Kumaun, trees having become stag headed and in some cases dying under its effects. It is doubtless due to the long drought that this scale has increased in such numbers as to infest the trees to a very considerable extent (*cf.* Plate VIII).

At the time of its discovery the scales were mature and the female insects inside them were engaged in egg laying, or the scales consisted simply of masses of eggs surrounded by a dried shrivelled female skin.

The minute larvæ swarmed from these eggs about the fourth week in June in Dehra Dun, to which place they were taken on the 15th of the month. It is probable that in their natural habitat they leave the scales at the commencement of July, *i.e.,* at the break of monsoon. The larvæ on swarming are minute little active creatures and appear to at first

confine themselves to the young twigs of the tree. As they grow older they go down to the larger branches and are to be found encrusting quite thick branches which have a coating of old bark and moss on them. At the same time, old scales may be found on the smallest green twigs, on leaves and leaf stalks and, more curious still, on unopened buds and on young acorns on the tree (see Plate VIII, figs. 1, 2).

The scale greatly resembles the lac scale (*Tachardia lacca*) in its habit of collecting together in dense masses on the branches, but it has not the power of exuding an exudation as is the case with the lacand so the scales do not become joined together in a solid mass. In colouring they bear a strong resemblance to oak branch bark and appear like small natural excrescences or warts on the branch; so much so that at a little distance it is impossible to distinguish a few scattered scales on a branch.

It is only when they are in the mumbers such as were to be seen this year (1908) that their presence attracts attention.

It is probable that the larvæ which hatched out towards the end of June spend the summer and autumn forming the scales on the trees, and that the old female insects in the scales pass through the winter beneath the scale, laying their eggs, as seen, in the spring and early summer.

Damage committed in the Forest.

It is perhaps too early to say what effect the appearance of this scale in large numbers would have upon an area of oak forest. It is more than probable, however, that the insect would be able to kill off weakly and sickly trees and young growth. That the present increase would appear to be due to climatic conditions favourable to the insect seems probable. We have yet, however, much to learn about the habits of this insect.

Points in the Life History requiring further observations.

These are many :—

(1) The period taken by the insect to pass through a single life cycle.

(2) Length of time spent by the young insect on the branches before it comes to rest and commences to form its scale around it.

(3) Length of time for the scale to reach full size.

(4) Time passed in the egg stage beneath the old scale covering.

(5) Distribution and abundance of the scale.

(6) Does it infest the *Moru* as well as the *Ban* oak ?

PLATE VIII.

FIG. 1, oak branch showing the method of infestation of the tree by the scale *Kermes himalayensis*, Green.

FIG. 2, portion of same, enlarged.

Half-tone.

M. E. Stebbing, *del.*

Survey of India Offices, Calcutta, 1909.

Kermes Himalayensis, Green on Quercus incana.

[*to face page 28.*

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THE

INDIAN FOREST RECORDS

A Note on the Fissibility of some Indian Woods

BY

R. S. TROUP, F.C.H.,
Imperial Forest Economist

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SUPERINTENDENT GOVERNMENT PRINTING, INDIA
Published in April 1910

INDIAN FOREST RECORDS.

Vol. II] 1909. [Part II

A Note on the Fissibility of some Indian Woods.

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1. Introductory.

Fissibility, or the capacity for being split, is under certain conditions an important property in wood, closely affecting, as it does, the utility or otherwise of wood employed for various purposes. Thus for split fuel fissibility is a decided advantage, whereas it is the reverse in the case of wood employed for any purpose in which it is subjected to great strain or shock. Again, the manner of splitting, particularly as regards the straightness of grain and the evenness of the split surface, is an important factor in the case of woods employed for such purposes as oars, carriage-shafts, wheel-spokes, sieve-frames, cask-staves, split shingles, basket-work, and many other purposes. Hence it will be seen that an accurate knowledge regarding the general qualities which affect the fissibility of wood, as well as the particular properties possessed by various woods in this connection, is of considerable importance.

Little has been known hitherto regarding the relative fissibility of various Indian woods or the manner in which different woods behave when acted on by a splitting-wedge. In order to make a commencement in compiling information on the subject, therefore, the writer recently carried out splitting tests at Dehra Dun with 61 different species of Indian woods. The results of these tests are given below; these results, it may be mentioned, are in some respects not entirely in accordance with accepted theories.

2. Woods Tested.

The following is an alphabetical list of the woods tested, the numbers in brackets referring to the relative order of fissibility as given in the Appendix :—

(1) Abies Pindrow. (3).
(2) Acacia Catechu (20).
(3) Adina cordifolia (31).
(4) Ægle Marmelos (48).
(5) Æsculus indica (9).
(6) Albizzia procera (21).
(7) Do. stipulata (45).
(8) Anogeissus latifolia (48).
(9) Bauhinia retusa (58).
(10) Berrya Ammonilla (32).
(11) Bombax malabaricum (44).
(12) Boswellia serrata (9).
(13) Bridelia retusa (40).
(14) Buchanania latifolia (26).
(15) Calophyllum spectabile (53).
(16) Carallia integerrima (14).
(17) Cassia Fistula (26).
(18) Casuarina equisetifolia (42).
(19) Cedrela Toona (38).
(20) Cedrus Deodara (7).
(21) Chloroxylon Swietenia (56).
(22) Dalbergia latifolia (58).
(23) D. Oliveri (60).
(24) D. Sissoo (52).
(25) Dipterocarpus tuberculatus (25.
(26) Gardenia gummifera (50).
(27) G. latifolia (15).
(28) G. lucida (35).
(29) G. turgida (30).
(30) Garuga pinnata (35).
(31) Gmelina arborea (46).
(32) Grewia vestita (41).
(33) Holoptelea integrifolia (46).
(34) Homalium tomentosum (6).
(35) Kydia calycina (34).
(36) Lagerstrœmia parviflora (29).
(37) L. tomentosa (16).
(38) Mallotus philippinensis (21).
(39) Odina Wodier (18).
(40) Oroxylum indicum (23).
(41) Ougeinia dalbergioides (61).
(42) Picea Morinda (8).
(43) Pinus excelsa (4).
(44) P. longifolia (9).
(45) Podocarpus neriifolia (9).
(46) Populus citiata (18).
(47) Pterocarpus macrocarpus (32).
(48) P. Marsupium (57).
(49) Pterospermum acerifolium (53).
(50) Quercus dilatata (51).
(51) Q. semecarpifolia (43).
52) Schrebera swietenioides (23).
53) Semecarpus Anacardium (16).
(54) Shorea robusta (55).
(55) Spondias mangifera (9).
(56) Sterculia villosa (2).
(57) Taxus baccata (1).
(58) Tectona grandis (5).
(59) Terminalia belerica (37).
(60) T. tomentosa (39).
(61) Zizyphus Xylopyrus (26).

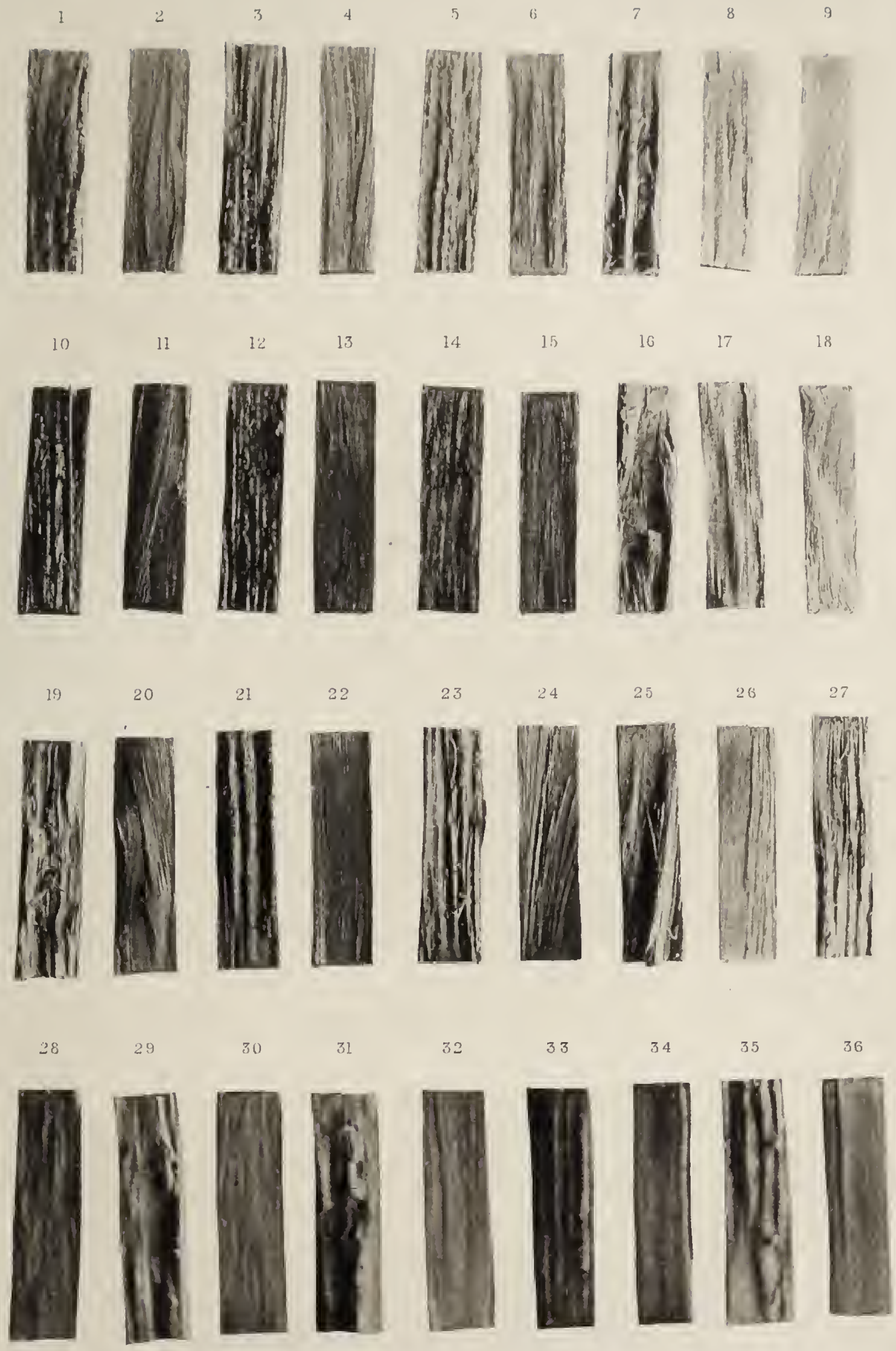
3. Method of Testing.

Tests were carried out with blocks of wood $5\frac{1}{2}'' \times 1\frac{1}{2}'' \times 1\frac{1}{2}''$ cut with the grain, the relative splitting force of which the fissibility is the converse being measured by the number of blows of constant strength required to split the blocks completely. The apparatus employed is described in section 4 below. Tests were carried out by splitting in a

PLATE I.

1.	Ougeinia dalbergioides	Radial.
2.	Do. do.	Tangential.
3.	Pterocarpus Marsupium	Radial.
4.	Do. do.	Tangential.
5.	Do. macrocarpus	Radial.
6.	Do. do.	Tangential.
7.	Cedrela Toona	Radial (with cross grain).
8.	Do. do.	Do. (with straight grain).
9.	Do. do.	Tangential.
10.	Dalbergia latifolia	Radial.
11.	Do. do.	Tangential.
12.	Do. Oliveri	Radial.
13.	Do. do.	Tangential.
14.	Do. Sissoo	Radial.
15.	Do. do.	Tangential.
16.	Anogeissus latifolia	Radial (coarsely wavy).
17.	Do. do.	Do. (finely wavy).
18.	Do. do.	Tangential.
19.	Chloroxylon Swietenia	Radial.
20.	Do. do.	Tangential.
21.	Shorea robusta	Radial.
22.	Do. do.	Tangential.
23.	Bauhinia retusa	Radial.
24.	Do. do.	Tangential.
25.	Terminalia belerica	Radial.
26.	Do. do.	Tangential.
27.	Do. tomentosa	Radial.
28.	Do. do.	Tangential.
29.	Pterospermum acerifolium	Radial.
30.	Do. do.	Tangential.
31.	Garuga pinnata	Radial.
32.	Do. do.	Tangential.
33.	Berrya Ammonilla	Radial.
34.	Do. do.	Tangential.
35.	Albizzia procera	Radial.
36.	Do. do.	Tangential.

PLATE I



Photogravure

Survey of India Offices, Calcutta, August 1909.

Plate II.

37.	Gardenia latifolia - -	Radial.
38.	Do. do. - - -	Tangential.
39.	Do. lucida - - -	Radial.
40.	Do. do. - - -	Tangential.
41.	Do. turgida - - -	Radial.
42.	Do. do. - - -	Tangential.
43.	Do. do. - - -	Radial.
44.	Do. do. - - -	Tangential.
45.	Grewia vestita - - -	Radial.
46.	Do. do. - - -	Tangential.
47.	Tectona grandis (plantation grown) -	Radial.
48.	Do. do. - - -	Tangential.
49.	Do. grandis (naturally grown) - -	Radial.
50.	Do. do. - - -	Tangential.
51.	Quercus semecarpifolia - -	Radial.
52.	Do. do. - - -	Tangential.
53.	Do. do. - - -	Radial.
54.	Do. do. - - -	Tangential.
55.	Cedrus Deodara - - -	Radial.
56.	Do. do. - - -	Tangential.
57.	Picea Morinda - - -	Radial.
58.	Do. do. - - -	Tangential.
59.	Pinus longifolia - - -	Radial.
60.	Do. do. - - -	Tangential.
61.	Abies Pindrow - - -	Radial.
62.	Do. do. - - -	Tangential.
63.	Taxus baccata - - -	Radial.
64.	Do. do. - - -	Tangential.
65.	Sterculia villosa - - -	Radial.
66.	Do. do. - - -	Tangential.
67.	Bombax malabaricum - - -	Radial.
68.	Do. do. - - -	Tangential.
69.	Odina Wodier - - -	Radial.
70.	Do. do. - - -	Tangential.
71.	Carallia integerrima - - -	Radial.
72.	Do. do. - - -	Tangential.

PLATE II

Photogravure

Survey of India Offices Calcutta August 1909

longitudinal direction only, that is, in the direction of the axis of the log ; no tests were made by splitting in a direction at right angles to the axis, though such tests would form an interesting subject for future experiment.

These longitudinal splitting tests were carried out in a radial as well as in a tangential direction, the blocks being specially cut so that one pair of sides was parallel to the radius of the log and the other at right angles to it.

It was found by trial that when longitudinal splitting is carried out between the tangential and the radial direction, the force necessary to split the block lies between that required to split in a tangential and that required to split in a radial direction, the actual relative splitting force (see section 4) approximating to the radial or the tangential splitting force according to the acuteness of the angle between the plane of fission and that of the radial or tangential surface respectively. Hence it was found sufficient to split in the radial and tangential directions only, the average relative splitting force being taken as the mean between the two. In most cases six tests were carried out with each sample (log) of wood, three in a radial and three in a tangential direction ; the results are tabulated in detail in the Appendix.

For purposes of comparison the relative splitting forces of *seasoned* wood only are taken, because not only can such wood be conveniently obtained in much greater variety than green wood, but it is more constant as regards moisture percentage, which affects fissibility to a considerable extent, the percentage of moisture in green wood varying greatly according to the time the wood has lain after felling ; further it is not always possible to obtain absolutely fresh-felled wood for testing purposes. In the case of 16 woods, however, tests have been carried out with green wood, while specimens cut from the same log and allowed to season thoroughly were also tested for comparison. The results are somewhat surprising, as they effectually contradict the accepted theory that green wood splits more easily than dry wood.

During these splitting tests special note was taken of the manner in which the various woods were affected by the splitting, particularly as regards grain and surface ; these observations are recorded in the remarks column of the Appendix, while Plates I and II show various types of surfaces produced by splitting, references to which are made in the remarks column of the Appendix.

4. Apparatus Employed.

The object of these tests being to obtain comparative figures showing the amount of force necessary to split pieces of wood of different kinds, an apparatus had to be devised which would effect this result. After various trials the apparatus depicted in Plates III and IV was constructed, the dimensions being as shown.

The machine, which is made of sissoo wood, consists of a hammer-shaft (*a*) working on an axis (*b*) in a strong fixed support, and fitted at its other extremity with a gun-metal hammer-head (*c*). This hammer-head is allowed to fall from a given height by its own weight on to a steel wedge (*d*) of given dimensions; the wedge acts perpendicularly downwards and splits the block of wood (*e*) which is held by means of an iron clamping-socket (*f*) vertically below the wedge. The force necessary to split any wood specimen is measured by the *number of blows required to drive the wedge through the wood* until the expanded head of the wedge (*h*) comes in contact with the platform (*j*). This figure we may term the *relative splitting force*: the fissibility of the wood is the converse of this force.

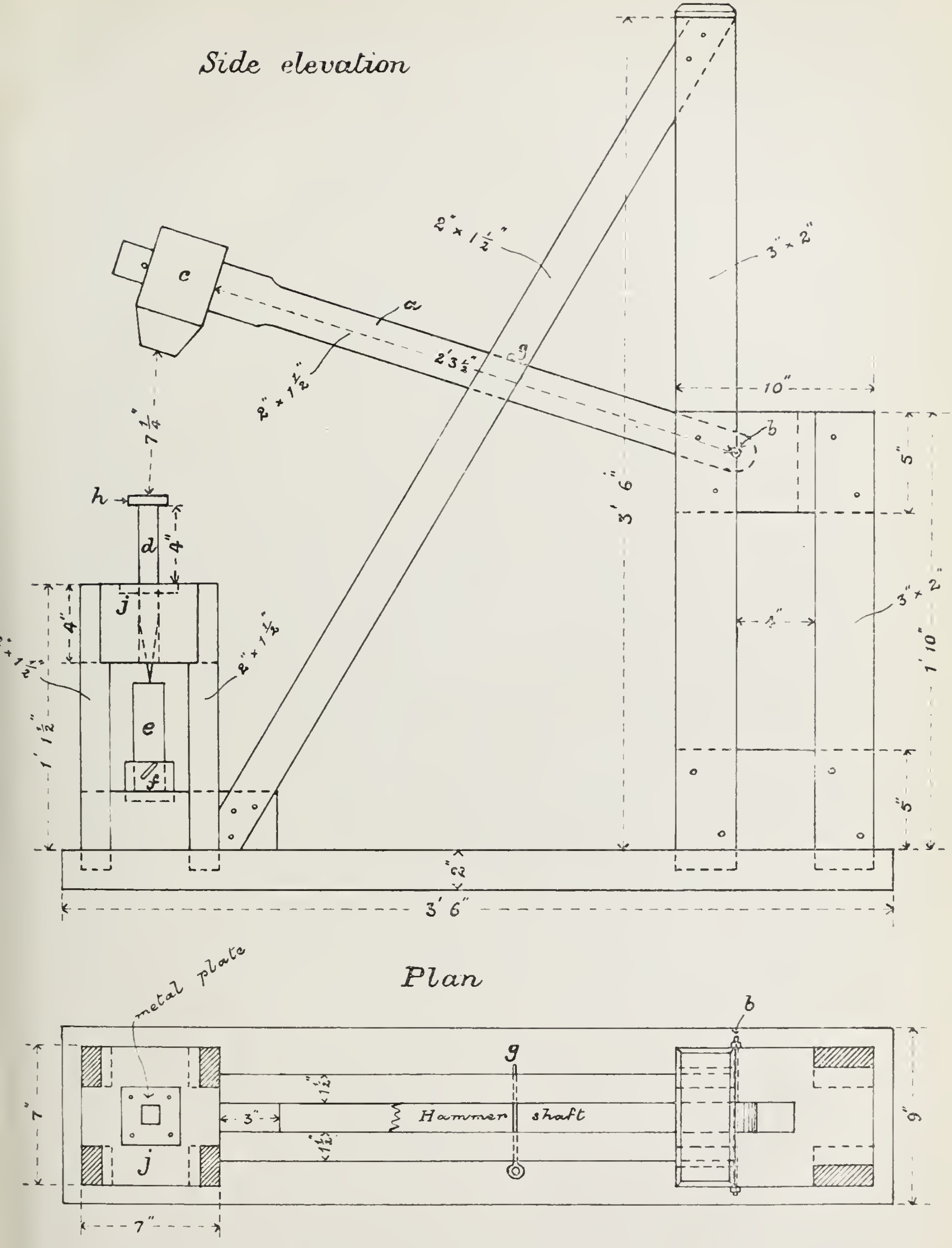
From the above description it is evident that the relative splitting force is an entirely arbitrary one, depending on the size of the wood specimen to be split, the weight and dimensions of the wedge, the weight of the hammer and the distance through which it falls. Many preliminary trials were made to ascertain the most suitable size of specimen, weight of hammer and falling distance, and the following dimensions and weights were ultimately adopted :—

(1) Weight of hammer-head alone, detached . .	9 lbs. 14 oz.
(2) Weight of hammer-head and shaft (the latter not being detached from the axis (*b*) and the scale-pan being placed under the hammer-head at a distance of $4\frac{1}{2}$ inches above the platform J) .	$11\frac{1}{2}$ lbs.
(3) Weight of wedge	2 lbs. 15 ozs.
(4) Size of wood-specimen	$5\frac{1}{2}'' \times 1\frac{1}{2}'' \times 1\frac{1}{2}''$.

The remaining dimensions necessary are given in the diagrams, the hammer being shown in the position to which it is raised immediately before being allowed to fall, an iron pin (*g*) preventing its being raised above the desired height. The hammer is repeatedly raised by hand to this position and allowed to fall on the wedge until the wood specimen is split through.

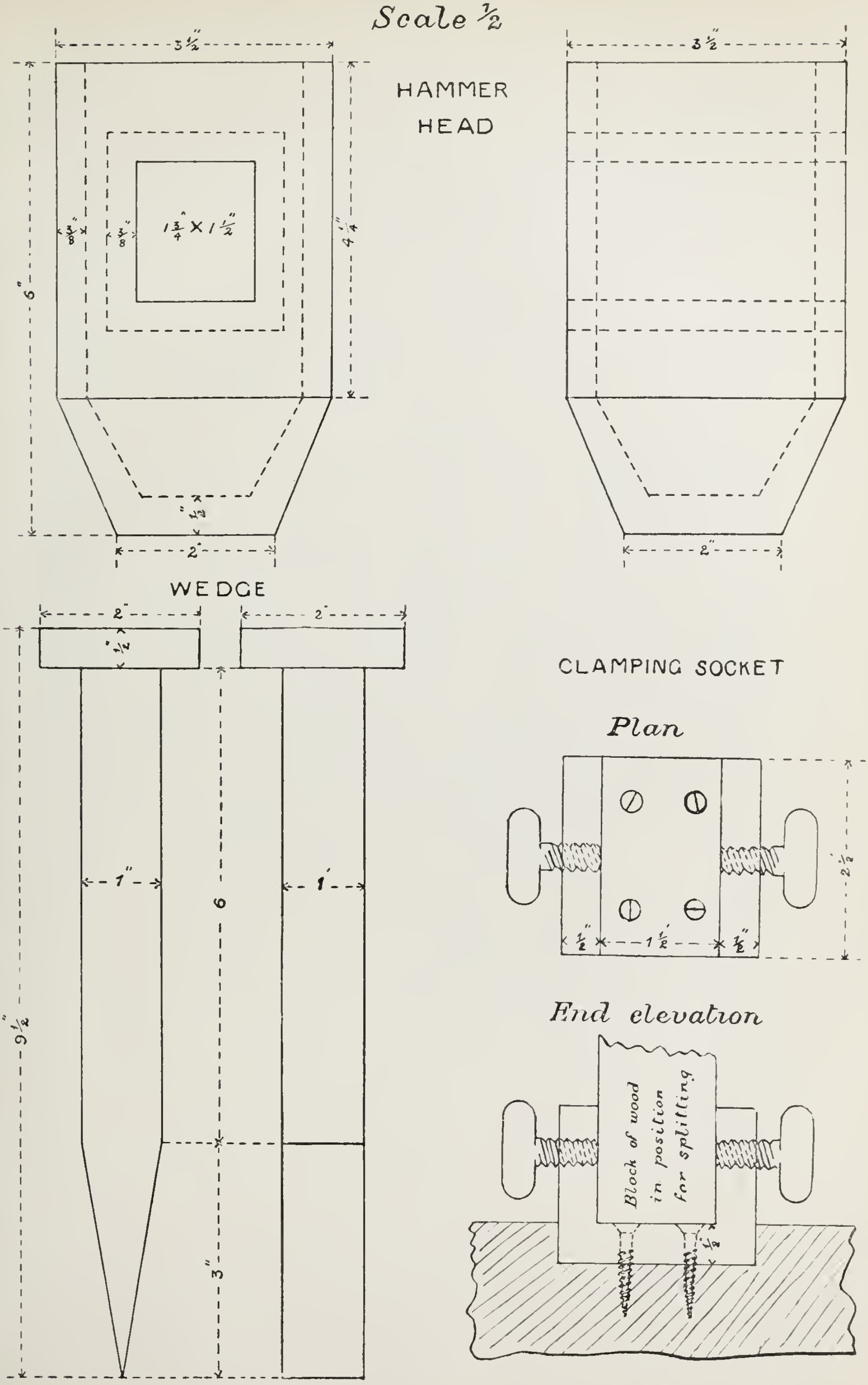
PLATE III.—DIAGRAM OF SPLITTING MACHINE.

Scale $1\frac{1}{2}'' = 1'$, *or* $\frac{1}{8}$.



(Wedge, hammer-head and part of hammer-shaft removed.)

PLATE IV. DETAILS OF HAMMER-HEAD, SPLITTING-WEDGE, AND CLAMPING SOCKET.



The hammer-head was made hollow in order that lead could be added inside it should its weight have proved insufficient; further weight, however, was found to be unnecessary with samples of the size adopted.

The wedges, which are made accurately to scale, are not resharpened on becoming worn out, but are replaced by new ones of exactly the same dimensions.

In order to give free play to the wood-specimen during splitting, the clamping-screws are not tightened more than is necessary, and the ends of the clamping-socket are open in order to prevent the splitting wood from holding together by artificial means.

5.—Results.

(1) **General.** The Appendix contains details of all the tests made, the woods being arranged in order of fissibility. It will be noticed that in many cases the individual splitting forces often vary greatly for the same species, even in the case of different blocks cut from one and the same log. These variations are not due to experimental errors, but to the fact that in a non-homogeneous substance like wood the relative splitting forces must of necessity vary, this variation being greater the less the homogeneity of the wood in question; thus coniferous woods, which, if free fro knots, are among the most homogeneous of woods, show little variation in the relative splitting forces of the various blocks tested, whereas cross-grained woods, such as *Shorea robusta, Cedrela Toona, Pterospermum acerifolium, Ougeinia dalbergioides* and others show great variation, owing to the fact that the degree of inclination of the cross fibres varies greatly, not only in different logs of the same species, but even in closely adjacent parts of one and the same log.

(2) **Various Factors which affect the Fissibility of Wood.**

(a) **Anatomical Structure.** Among the factors which influence the fissibility of wood the most important is undoubtedly its *anatomical structure*, and particularly the straightness or crossness of grain. Woods, whether hard or soft, which have straight grain, invariably split more easily than those with cross-fibres, at any rate where radial fission is concerned. Thus the samples of *Acacia Catechu*, in which the grain was straight, split with comparative ease, although the wood is one of the hardest, whereas much softer woods with cross-fibres, such as *Garuga pinnata, Bombax malabaricum, Gmelina arborea, Cedrela Toona* and other fairly soft woods, required on an average more

force to split them, owing to the cross-grained structure of some of the blocks tested. In every case the cross-grained structure appeared on the radial and not on the tangential section. As evidence of the influence of cross-grain on the fissibility of woods, it will be seen that Nos. 1 to 15, that is, the most fissile woods, all have straight grain, whereas Nos. 52 to 61, that is, the least fissile woods, are all cross-grained. In general it may be said that anything which interferes with the straightness of the grain, such as the presence of knots and dormant buds, or obliqueness or waviness of the fibres, reduces the fissibility of the wood.

The presence of large *medullary rays* is generally, and no doubt rightly, held to increase the fissibility of wood in a radial direction. As far as the present tests go, the number of specimens tested was hardly sufficient to form the basis of independent conclusions on this point. Of the woods tested which have large medullary rays, *Carallia integerrima* split more easily in a radial than in a tangential direction, the difference however being small; *Casuarina equisetifolia,* on the other hand, was more fissile in the tangential direction. The results in the case of the two oaks tested can hardly be considered conclusive. In the case of *Quercus semecarpifolia* there was no appreciable difference between the forces required for radial and tangential splitting; the medullary rays, however, were not very conspicuous on the radial section. In the case of *Q. dilatata* fission was slightly easier in the radial than in the tangential direction, but two of the specimens used for the tangential splitting test were knotty.

(b) Hardness.

As far as these tests show, hardness has far less influence on the fissibility of a wood than anatomical structure. This is particularly the case with straight-grained woods; thus *Homalium tomentosum* and *Acacia Catechu,* both hard woods with straight grain, split without difficulty. In the case of cross-fibred woods hardness has considerable influence, for in the case of such woods the wedge is driven through the block by severing the cross-fibres transversely as well as by tearing them out; this process is accomplished with more ease in the case of soft woods than in the case of hard woods. The cross-fibres of such soft woods as *Bombax malabaricum, Garuga pinnata,* and *Oroxylum indicum* were cut across in this way with comparative ease, whereas in the case of such hard cross-fibred woods as *Ougeinia dalbergioides, Dalbergia latifolia, D. Oliveri, Pterocarpus Marsupium, Shorea robusta* and others, the tough hard fibres either were cut through with

great difficulty or refused to be cut through at all, the wood being ultimately split only after repeated blows which gradually tore out the fibres in the form of rough splinters. In such cases the primary cause of difficulty in splitting, however, was the crossness of the grain rather than the hardness of the wood.

(c) Direction in which the force acts. Radial as compared with tangential cleavage.

Text-books tell us that wood splits more easily in a radial than in a tangential direction. This may possibly hold with most European woods, but the reverse is certainly the case as far as the great majority of Indian woods are concerned, judging from the results of the tests described in this Article, for of the 61 woods tested the splitting was easier along the tangential plane in 43 woods, and easier along the radial plane in 11 woods, while in the remaining 7 woods the splitting force was identical in each plane. The results tabulated in the Appendix show that of the 11 woods where fissibility is greater in the radial direction, in every case the difference between the radial and tangential splitting force is less than 2 units, while of these as many as 9 woods show a difference of only one unit or less. Thus in no case is radial splitting markedly more easy than tangential splitting. On the other hand this difference amounts to over 10 units in nine different woods where the splitting force is greater in the radial than in the tangential direction, the difference being as much as 87·29 units for *Ougeinia dalbergioides*, 33·5 units for *Dalbergia Oliveri*, 21 units for *Dalbergia latifolia*, 20 units for *Bauhinia retusa*, and 19·33 units for *Pterocarpus Marsupium*. In the case of *Dalbergia Oliveri*, splitting in a radial direction is more than 17 times as difficult as it is in a tangential direction; in *Ougeinia dalbergioides* it is more than 13 times, in *Pterocarpus Marsupium* more than 12 times, in *Shorea robusta* more than 9 times and in *Dalbergia latifolia* 7 times, while in many other woods the difficulty of splitting radially as compared with tangentially is much more marked than in any of the woods where radial fission is the easier.

Finally, if we take the average splitting force for all the 61 woods, we find it to be 7·79 for radial and 2·92 for tangential splitting in the case of dry wood. As the woods tested may be taken to be fairly representative, the results prove beyond doubt that, as far as Indian species are concerned, wood as a general rule splits a good deal more easily along a tangential than along a radial plane. It has already been mentioned that cross-grain is encountered during radial and not during

tangential splitting, and it is this fact which is generally responsible for any great excess of force required for splitting in a radial, as compared with a tangential direction.

(d) Moisture.

According to Gayer, European hard woods are more fissile when wet and soft woods are more fissile when dry. This is not borne out in the case of Indian woods by the present tests, for of the 16 woods tested in this respect all split more easily when dry than when wet except one, *Sterculia villosa*, which required the same splitting force for green and dry wood. The green and dry specimens of each species were cut from the same log from a freshly-felled tree, some being tested while quite green and the remainder being kept till thoroughly seasoned. The explanation why green wood splits with more difficulty than dry wood no doubt is that the moisture toughens the fibres : hence, as we might expect, the greatest disparity in the relative forces required for splitting green and dry wood exists in cross-fibred woods, such as *Cedrela Toona, Shorea robusta, Bombax malabaricum, Anogeissus latifolia,* and *Dalbergia Sissoo,* where the cross-fibres have to be cut across or torn apart with difficulty, whereas in straight-grained woods such as *Kydia calycina, Cassia Fistula, Acacia Catechu, Sterculia villosa* and others the disparity is small or non-existent.

(3) **Surfaces produced by Splitting.** As a general rule the tangential surface of fission is smoother and straighter than the radial surface, this being particularly marked in the case of cross-grained woods. In the remarks column of the Appendix will be found notes regarding the surfaces produced on the various specimens tested, these being also illustrated in Plates I and II.

There are some characteristic types of surface produced by the splitting of certain classes of wood, the following being worthy of special remark :—

(*a*) *Conifers.* As a general rule the radial surface consists of parallel ridges and furrows corresponding to the annual rings, while the tangential surface is apt to curve in the direction of the annual rings, being smooth until it intersects an annual ring, when it becomes broken.

(*b*) *Gardenias* have a characteristic flaky or almost conchoidal fracture, the surface being covered with irregular hollows and undulations ; this is usually more marked on the radial than on the tangential surface. This structure is noticeable also in *Schrebera swietenioides.*

(c) *Cross-grained woods* show on the radial surface a series of ridges and furrows, usually in parallel rows, the depth and roughness of the furrows depending chiefly on the degree of "crossness" of the grain. The tangential surface does not show this structure, being comparatively smooth. The ridges and furrows referred to appear to correspond, in some cases at least, with the concentric rings of growth, the fibres altering their course with each successive ring : whether or not this is universally the case it is difficult to say, as the concentric rings cannot be distinguished clearly in many cross-grained woods.

6. Further Experiments Desirable.

The experiments described here, although they extend to a fair number of common Indian woods and some rarer ones, do not pretend to be exhaustive, and it is desirable that they should be supplemented from time to time by further tests. The splitting apparatus is at the Forest Research Institute, Dehra Dun, and similar tests can be carried out without difficulty in the case of woods which Forest Officers and others may be good enough to send for the purpose.

APPEN

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT											
				Green Wood								Dry			
				Radial.				Tangential.				Radi			
				1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Taxus baccata	...	Jaunsar, United Provinces.	...	...	...	...	...	...	...	...	2	1	1	...
2	Sterculia villosa	...	Dehra Dun .	2	1	1	1·33	2	1	1	1·33	1	2	2	...
3	Abies Pindrow	1	Jaunsar, United Provinces.	...	...	...	...	...	...	...	...	1	1	...	...
		2	Do. .	...	...	...	...	...	...	...	...	1	1	1	...
		3	Do. .	...	...	...	...	...	...	...	...	2	1	1	...

DIX.

Woods arranged in order of Fissibility.

TING FORCES.

WOOD.								GENERAL AVERAGE, RADIAL AND TANGENTIAL.			REMARKS. (NOTE.—*Rad.* refers to the radial and *Tan.* the tangential fissure.)
al.		Tangential.						Green wood.	Dry wood.		
Average of columns 13, 14, 15 and 16.						Average of columns 19, 20, 21 and 22.					
For separate samples.	For all samples of same species.	1	2	3	4	For separate samples.	For all samples of same species.	Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
17	18	19	20	21	22	23	24	25	26	27	28
...	1·33	1	1	1	...	...	1	...	...	1·17	*Rad.*—Grain straight: surface smooth, with slight longitudinal furrowing. *Tan.*—Smooth and shiny, with numerous small longitudinal indentations: tends to follow the curve of the annual cylinders. [*Vide* Plate II, Nos. 63 and 64.]
...	1·67	1	1	1	...	...	1	1·33	...	1·33	*Rad.*—Straight and clean: medullary rays very conspicuous. *Tan.*—Straight and clean. [*Vide* Plate II, Nos. 65 and 66.]
1	1·12	2	2	2	2	2	1·89	...	1·5	1·5	*Rad.*—Grain straight: surface varying from fairly smooth to conspicuously furrowed, longitudinally along lines corresponding with the annual rings. *Tan.*—Very smooth. [*Vide* Plate II, Nos. 61 and 62.]
1		2	1	2	...	1·67		...	1·33		
1·33		2	2	...	...	2		...	1·67		

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT											
				GREEN WOOD.								DRY			
				Radial.				Tangential.				Radi			
				1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
4	Pinus excelsa .	1	Jaunsar, United Provinces.	...	...	...	...	...	...	...	...	2	...	...	...
		2	Do. .	...	...	...	...	...	...	...	...	2	2	1	...
		3	Do. .	...	...	...	...	...	...	...	...	1	...	...	...
		4	Do. .	...	...	...	...	...	...	...	...	1	2	2	...
5	Tectona grandis	1	Plantation grown teak from Myodwin plantation, Zigon Division, Burma.	...	...	...	...	...	...	...	...	2	2	1	...
		2	Naturally grown teak from Burma.	...	...	...	...	...	...	...	...	2	3	3	...
6	Homalium tomentosum.	...	Toungoo, Burma	...	...	...	...	...	...	...	...	2	1	2	...

Woods arranged in order of Fissibility—continued.

TING FORCES.											
WOOD.								GENERAL AVERAGE, RADIAL AND TANGENTIAL.			REMARKS.
al.		Tangential.						Green wood.	Dry wood.		
Average of columns 13, 14, 15 and 16.						Average of columns 19, 20, 21 and 22.					(NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
For separate samples.	For all samples of same species.	1	2	3	4	For separate samples.	For all samples of same species.	Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
17	18	19	20	21	22	23	24	25	26	27	28
2	1·62	2	...	...	...	2	1·75	...	2	1·68	*Rad.*—Grain straight: surface marked by longitudinal furrows corresponding with the annual rings. *Tan.*—Straight and smooth, sometimes curving slightly along the annual cylinders.
1·67		3	2	2	...	2·33		...	2		
1		1	...	...	...	1		...	1		
1·67		1	2	1	...	1·33		...	1·5		
1·67	2·17	1	1	2	...	1·33	13·3	...	1·5	1·75	No. 1.—*Rad.*—Grain straight but surface somewhat rough with longitudinal furrows. *Tan.*—Very straight and smooth. No. 2.—*Rad.*—Grain straight with slight longitudinal furrowing and splintering. *Tan.* —Straight and smooth, with occasional fine longitudinal splintering. Growth slower than No. 1. [*Vide* Plate II, Nos. 47 to 50.]
2·67		1	2	1	...	1·33		...	2		
...	1 67	2	2	2	...	...	2	...	...	1 83	*Rad.*—Grain straight, surface fairly smooth, with slight longitudinal furrows. *Tan.*—Straight and smooth.

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT											
				GREEN WOOD.								DRY			
				Radial.				Tangential.				Radi			
				1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
7	Cedrus Deodara	1	Jaunsar, United Provinces.	...	...	...	...	...	...	...	...	1	3	2	...
		2	Do.	...	...	...	...	...	...	...	...	4*	...	...	...
		3	Do.	...	...	...	...	...	...	...	...	1	...	...	...
8	Picea Morinda	1	Jaunsar, United Provinces.	...	...	...	...	...	...	...	...	3	2	2	...
		2	Do.	...	...	...	...	...	...	...	...	1	...	...	...
		3	Do.	...	...	...	...	...	...	...	...	2	2	1	...

Woods arranged in order of Fissibility—continued.

TING FORCES. WOOD. a l. Average of columns 13, 14, 15 and 16. For separate samples.	For all samples of same species.	Tangential. 1	2	3	4	Average of columns 19, 20, 21 and 22. For separate samples.	For all samples of same species.	GENERAL AVERAGE, RADIAL AND TANGENTIAL. Green wood. Average of columns 8 and 12.	Dry wood. For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	REMARKS. (NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
17	18	19	20	21	22	23	24	25	26	27	28
2		1	1	...	...	1		...	1·5		
4	2·2	3*	...	...	...	3	1·5	...	3·5	1·85	*Rad.*—Grain straight, surface marked by longitudinal furrows corresponding with the annual rings. *Tan.*—Straight and smooth, sometimes curving slightly along the annual cylinders. * These two specimens had small knots in them, reducing their fissibility. [*Vide* Plate II, Nos. 55 and 56.]
1		1	...	...	...	1		...	1		
2·33		2	2	...	...	2		...	2·17		
1	1·86	2	...	...	...	2	2	..	1·5	1·93	*Rad.*—Grain straight, surface marked by longitudinal furrows corresponding with the annual rings. *Tan.*—Straight and smooth, sometimes curving slightly along the annual cylinders. [*Vide* Plate II, Nos. 57 and 58.]
1·67		2	2	2	...	2		...	1·83		

Details of Splitting Tests with various Indian

				RELATIVE SPLIT											
				Green Wood.								Dry			
				Radial.				Tangential.				Radi			
Order of fissibility.	Name.	Sample Number.	Locality.	1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
9	Æsculus indica	...	Jaunsar, United Provinces.	...	...	...	...	...	...	...	...	2	2	2	...
	Pinus longifolia	...	Jaunsar, United Provinces.	...	...	...	...	...	...	...	...	2	2	2	...
	Spondias mangifera.	...	Dehra Dun .	...	...	...	...	...	...	...	...	2	2	2	...
	Boswellia serrata.	...	Do. (Siwaliks).	...	...	...	...	...	...	...	...	2	2	...	...
	Podocarpus neriifolia.	...	Andamans .	...	...	...	...	...	...	...	...	2	2	2	...

Woods arranged in order of Fissibility—continued.

TING FORCES.											
WOOD.								GENERAL AVERAGE, RADIAL AND TANGENTIAL.			REMARKS. (NOTE.—*Rad* refers to the radial and *Tan* to the tangential fissure.)
al.		Tangential.						Green wood.	Dry wood.		
Average of columns 13, 14, 15 and 16.						Average of columns 19, 20, 21 and 22.					
For separate samples.	For all samples of same species.	1	2	3	4	For separate samples.	For all samples of same species.	Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
17	18	19	20	21	22	23	24	25	26	27	28
...	2	2	2	2	...	...	2	...	...	2	*Rad.*—Grain straight to wavy: surface slightly rough with longitudinal furrows. *Tan.*—Grain straight: surface smooth to slightly rough.
...	2	2	2*	2*	...	...	2	...	...	2	*Rad.*—Grain straight: surface furrowed with longitudinal furrows corresponding with the annual rings. *Tan.*—Grain straight: surface inclined to be furrowed longitudinally. * These two specimens were somewhat knotty. [*Vide* Plate II, Nos. 59 and 60.]
...	2	2	2	2	...	...	2	...	...	2	*Rad.* and *Tan.*—Grain straight: surface fairly smooth.
...	2	2	2	...	...	...	2	...	...	2	*Rad.*—Grain straight: surface somewhat rough. *Tan.*—Grain straight: surface smoother than on radial section, with small longitudinal furrows.
...	2	2	2	2	...	...	2	...	...	2	*Rad.*—Grain straight: surface somewhat rough with longitudinal furrows. *Tan.*—Similar but with smoother surface.

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT											
				GREEN WOOD.								DRY			
				Radial.				Tangential.				Radi			
				1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
14	Carallia integerrima.	1	Rangoon Division, Burma.	...	...	...	...	...	...	...	...	3	2	2	...
		2	Dehra Dun .	...	...	...	...	...	..	...	...	2	1	1	...
15	Gardenia latifolia.	...	Raipur, Central Provinces.	...	...	...	...	...	..	...	...	4	2	2	...
16	Lagerstrœmia tomentosa.	...	Pyinmana, Upper Burma.	...	...	...	...	...	...	...	...	3	5	3	...
	Semecarpus Anacardium.	...	Dehra Dun.	...	...	...	...	...	...	...	...	2	1	2	...

Woods arranged in order of Fissibility—continued.

TING FORCES. WOOD. al. Average of columns 13, 14, 15 and 16. For separate samples.	Average of columns 13, 14, 15 and 16. For all samples of same species.	Tangential. 1	Tangential. 2	Tangential. 3	Tangential. 4	Tangential. Average of columns 19, 20 21 and 22. For separate samples.	Tangential. Average of columns 19, 20 21 and 22. For all samples of same species.	GENERAL AVERAGE, RADIAL AND TANGENTIAL. Green wood. Average of columns 8 and 12.	GENERAL AVERAGE, RADIAL AND TANGENTIAL. Dry wood. For separate samples. Average of columns 17 and 23.	GENERAL AVERAGE, RADIAL AND TANGENTIAL. Dry wood. For all samples of same species. Average of columns 18 and 24.	REMARKS. (NOTE —*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
17	18	19	20	21	22	23	24	25	26	27	28
2·33	1·83	2	3	3	...	2·67	2·5	...	2·5	2·16	*Rad.*—Grain straight: surface very rough with the broken large medullary rays and splintered brittle fibres. *Tan.*—Grain straight: surface covered with small longitudinal furrows formed by the large vessels and broken brittle fibres. [*Vide* Plate II, Nos. 71 and 72.]
1·33		2	3	2	...	2·33		...	1·83		
...	2·67	1	2	2	...	...	1·67	...	...	2·17	*Rad.*—Grain straight to wavy: surface broken with a flaky appearance characteristic of the Gardenias. *Tan.*—Similar, but with a smoother surface. [*Vide* Plate II, Nos. 37 and 38.]
...	3·67	1	1	1	...	...	1	...	...	2·33	*Rad.*—Slightly cross-grained. *Tan.*—Grain straight to very slightly wavy.
...	1·67	4	3	2	...	...	3	...	..	2·33	*Rad.*—Grain straight: surface fairly smooth. *Tan.*—Grain straight: surface with small longitudinal furrows.

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT											
				GREEN WOOD.								DRY			
				Radial.				Tangential.				Radi			
				1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	Populus ciliata	...	Jaunsar, United Provinces.	...	...	...	...	...	...	...	...	2	...	...	...
	Odina Wodier (Sapwood).	...	Dehra Dun .	..	...	...	...	...	...	...	...	3	2	3	...
20	Acacia Catechu	1	Dehra Dun .	7	3	5	5	3	3	5	3·67	8	2	3	...
		2	Do. .	...	..	...	..	...	...	...	...	4	2	...	...

Woods arranged in order of Fissibility—continued.

TING FORCES.											
WOOD.								GENERAL AVERAGE, RADIAL AND TANGENTIAL.			REMARKS. (NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
al.		Tangential.						Green wood.	Dry wood.		
Average of columns 13, 14, 15 and 16.						Average of columns 19, 20, 21 and 22.					
For separate samples.	For all samples of same species.	1	2	3	4	For separate samples.	For all samples of same species.	Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
17	18	19	20	21	22	23	24	25	26	27	28
...	2	3	...	...	...	...	3	...	...	2·5	*Rad.*—Grain fairly straight: surface smooth and shiny. *Tan.*—Grain fairly straight: surface smooth. The latter specimen had a small knot in it, which rendered splitting more difficult than would otherwise have been the case.
...	2·67	2	3	2	...	...	2·33	...	...	2·5	*Rad.*—Grain straight: surface furrowed longitudinally. *Tan.*—Grain straight to slightly oblique; surface smooth. [*Vide* Plate II, Nos. 69 and 70.]
4·33	3·8	3	2	2	...	2·33	2·17	4·33	3·33	2·98	*Rad.*—Grain straight to wavy: surface fairly smooth with occasional slight longitudinal splintering, to rough with longitudinal furrows. *Tan.*—Grain straight to slightly wavy: surface flat or undulating, smooth or slightly furrowed longitudinally.
3		2	2	2	...	2		...	2·5		

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT — Green Wood. — Radial. — 1	2	3	Average of columns 5, 6 and 7.	Tangential. — 1	2	3	Average of columns 9, 10 and 11.	Dry — Radi — 1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
21	Mallotus philippinensis.	...	Dehra Dun .	...	...	...	...	...	...	...	...	3	3	3	...
	Albizzia procera	1	Dehra Dun .	5	6	7	6	3	3	3	3	3	4	2	...
		2	Do .	...	...	...	...	...	...	...	...	5	6	5	...
23	Oroxylum indicum.	...	Dehra Dun .	...	...	...	...	...	...	...	...	3	3	...	...
	Schrebera swietenioides.	...	Mandla, Central Provinces.	...	...	...	...	...	...	...	...	5	4	...	...

Woods arranged in order of Fissibility—continued.

TING FORCES.											
WOOD.								GENERAL AVERAGE, RADIAL AND TANGENTIAL.			
al.		Tangential.						Green wood.	Dry wood.		
Average of columns 13, 14, 15 and 16.						Average of columns 19, 20, 21 and 22.					REMARKS. (NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
For separate samples.	For all samples of same species.	1	2	3	4	For separate samples.	For all samples of same species.	Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
17	18	19	20	21	22	23	24	25	26	27	28
...	3	3	3	...	...	...	3	...	...	3	*Rad.*—Grain broadly wavy: surface undulating and somewhat jagged. *Tan.*—Grain broadly or slightly wavy: surface undulating and smoother than on the radial surface.
3	4·17	2	2	2	...	2	1·83	4·5	2·5	3	*Rad.*—Straight to cross-grained: surface with longitudinal furrows and sometimes splinters, the depth of the furrows varying with the extent of cross-grain. *Tan.*—Smooth and straight. [*Vide* Plate I, Nos. 35 and 36.]
5·33		1	2	2	...	1·67		...	3·5		
...	3	3	4	...	...	...	3·5	...	...	3·25	*Rad.*—Cross-grained: surface deeply furrowed by the cross fibres being torn out or severed. *Tan.*—Not cross-grained: surface undulating, fairly smooth, with small longitudinal furrows.
...	4·5	2	2	...	...	...	2	...	...	3·25	*Rad.*—Very rough and jagged, resembling the fracture of the Gardenias. *Tan.*—Smooth, but surface somewhat undulating.

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT											
				GREEN WOOD.								DRY			
				Radial.				Tangential.				Radi			
				1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
25	Dipterocarpus tuberculatus.	...	Rangoon Division, Burma.	...	...	...	...	...	...	...	...	3	3	5	...
26	Cassia Fistula.	...	Dehra Dun	9	6	3	6	1	2	2	1·67	2	5	7	...
	Buchanania latifolia.	...	Do.	...	...	...	...	..	...	...	...	3	6	4	...
	Zizyphus Xylopyrus.	...	Mandla, Central Provinces.	...	...	...	..	...	...	...	...	4	...	...	...

Woods arranged in order of Fissibility—continued.

TING FORCES.

WOOD.								General average, radial and tangential.			
al.		Tangential.						Green wood.	Dry wood.		
Average of columns 13, 14, 15 and 16.		1	2	3	4	Average of columns 19, 20, 21 and 22.					REMARKS. (NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure).
For separate samples.	For all samples of same species.					For separate samples.	For all samples of same species.	Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
17	18	19	20	21	22	23	24	25	26	27	28
...	3·67	3	4	2	...	...	3	...	...	3·33	*Rad.*—Grain fairly straight: surface somewhat rough. *Tan.*—Grain straight: surface slightly rough, with small longitudinal furrows.
...	4·67	1	3	3	...	...	2·33	3·83	...	3·5	*Rad.*—Straight to slightly cross-grained, with longitudinal furrowing and splintering. *Tan.*—Grain straight: surface smooth, with fine longitudinal furrows and sometimes fine splintering.
...	4·33	3	2	3	...	...	2·67	...	...	3·5	*Rad.*—Straight to slightly cross and oblique-grained, the weak cross-fibres being broken through: surface furrowed and splintered longitudinally. *Tan.*—Grain straight to slightly wavy: surface fairly smooth, with small longitudinal furrows.
...	4	3	...	...	...	...	3	...	...	3·5	*Rad.*—Grain staight: longitudinal elastic splinters on surface. *Tan.*—Grain straight, surface fairly smooth.

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT											
				GREEN WOOD.								DRY			
				Radial.				Tangential.				Radi			
				1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
29	Lagerstrœmia parviflora.	1	Dehra Dun .	6	5	3	4·67	3	4	5	4	2	3	2	...
		2	Mandla, Central Provinces.	...	...	...	...	...	...	...	...	6	...	...	...
30	Gardenia turgida.	1	Mandla, Central Provinces.	...	...	...	...	...	...	...	...	4	4	...	...
		2	Raipur, Central Provinces.	...	...	...	...	...	...	...	...	4	...	...	...
31	Adina cordifolia	...	Dehra Dun .	7	8	8	7·67	3	3	2	3·67	5	5	5	...

Woods arranged in order of Fissibility—continued.

TING FORCES.											
WOOD.								GENERAL AVERAGE, RADIAL AND TANGENTIAL.			
al.		Tangential.						Green wood.	Dry wood.		
Average of columns 13, 14, 15 and 16.						Average of columns 19, 20, 21 and 22.					REMARKS. (NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
For separate samples.	For all samples of same species.	1	2	3	4	For separate samples.	For all samples of same species.	Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
17	18	19	20	21	22	23	24	25	26	27	28
2·33	3·25	3	5	4	...	4	4	4·33	3·17	3·62	*Rad.*—Grain straight: surface finely to roughly furrowed longitudinally, and in some case splintered, the splintering being more pronounced in the green than in the dry specimens. *Tan.*—Grain straight: surface finely to roughly furrowed longitudinally.
6		4	...	...	...	4		...	5		
4	4	3	4	...	...	3·5	3·33	...	3·75	3·66	*Rad.*—Surface irregularly undulating with the flaky fracture characteristic of Gardenias but smoother than the other Gardenias tested. *Tan.*—Grain slightly wavy: surface smooth and very slightly undulating. [*Vide* Plate II, Nos. 41 to 44.]
4		3	...	...	..	3		..	3·5		
...	5	2	3	2	...	...	2·33	5·67	...	3·67	*Rad.*—Grain fairly straight: surface longitudinally furrowed and splintered. *Tan.*—Grain straight: surface smooth, with occasional slight splintering.

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT — GREEN WOOD. — Radial. — 1	2	3	Average of columns 5, 6 and 7.	Tangential. — 1	2	3	Average of columns 9, 10 and 11.	DRY — Radi — 1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
32	Pterocarpus macrocarpus.	...	Ruby Mines, Upper Burma.	...	...	...	...	...	...	...	...	6	7	4	...
32	Berrya Ammonilla.	...	Pyinmana, Upper Burma	...	...	...	...	...	...	...	...	3	6	8	...
34	Kydia calycina	1	Dehra Dun	8	5	9	7·33	2	3	2	2·33	4	6	4	...
		2	Do.	...	...	...	...	...	...	...	...	3	4	4	...

Woods arranged in order of Fissibility—continued.

TING FORCES. WOOD. al. Average of columns 13, 14, 15 and 16. For separate samples.	TING FORCES. WOOD. al. Average of columns 13, 14, 15 and 16. For all samples of same species.	WOOD. Tangential. 1	WOOD. Tangential. 2	WOOD. Tangential. 3	WOOD. Tangential. 4	WOOD. Tangential. Average of columns 19, 20, 21 and 22. For separate samples.	WOOD. Tangential. Average of columns 19, 20, 21 and 22. For all samples of same species.	GENERAL AVERAGE, RADIAL AND TANGENTIAL. Green wood. Average of columns 8 and 12.	GENERAL AVERAGE, RADIAL AND TANGENTIAL. Dry wood. For separate samples. Average of columns 17 and 23.	GENERAL AVERAGE, RADIAL AND TANGENTIAL. Dry wood. For all samples of same species. Average of columns 18 and 24.	REMARKS. (NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
17	18	19	20	21	22	23	24	25	26	27	23
...	5·67	2	2	2	...	...	2	...	...	3·83	*Rad.*—Somewhat cross-grained: surface furrowed longitudinally. *Tan.*—Grain straight to very slightly wavy, surface smooth. [*Vide* Plate I, Nos. 5 and 6.]
...	5·67	2	2	2	...	...	2	...	...	3·83	*Rad.*—Somewhat cross-grained to nearly straight grained. *Tan.*—Grain very straight: surface straight with fine longitudinal furrows. [*Vide* Plate I, Nos. 33 and 34].
4·67 3·67	4·17	3 4	4 3	4	... ...	3·67 3·5	3·60	4·83 ...	4·17 3·58	3·88	*Rad.*—Grain straight: surface with longitudinal furrows corresponding to the concentric rings, as in the case of conifers, and with occasional splinters, especially in the green specimens. *Tan.*—Grain straight: surface smooth to somewhat rough.

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT											
				Green Wood.								Dry			
				Radial.				Tangential.				Radi			
				1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
35	Gardenia lucida	...	Raipur, Central Provinces.	..	...	...	...	...	..	...	...	4	...	...	...
	Garuga pinnata	...	Dehra Dun	...	...	...	...	...	...	...	...	10	6	3	...
37	Terminalia belerica.	1	Dehra Dun	18	12	11	13 67	2	7	3	4	8	7	6	...
		2	Do.	...	...	...	...	...	...	...	...	2	3	3	...

Woods arranged in order of Fissibility—continued.

TING FORCES.

Wood.								General average, radial and tangential.			
al.		Tangential.						Green wood	Dry wood		
Average of columns 13, 14, 15 and 16.						Average of columns 19, 20, 21 and 22.					Remarks. (Note.—*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
For separate samples.	For all samples of same species.	1	2	3	4	For separate samples.	For all samples of same species.	Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
17	18	19	20	21	22	23	24	25	26	27	28
...	4	4	...	...	...	...	4	...	...	4	*Rad.*—Grain wavy and curly: surface deeply indented in the manner characteristic of Gardenias. *Tan.*—Surface not quite so deeply indented as on the radial section; a knot in this specimen increased the difficulty of splitting it. [*Vide* Plate II, Nos. 39 and 40.]
...	6·33	2	2	1	...	...	1·67	...	...	4	*Rad.*—Cross-grained: surface longitudinally furrowed, the weak cross-fibres being broken across. *Tan.*—Fairly straight and smooth. [*Vide* Plate I, Nos. 31 and 32.]
7	4·83	4	3	...	...	3·5	3·4	8·83	5·25	4·11	*Rad.*—Sample No. (1) surface furrowed, with much splintering longitudinally, especially in the green specimens: sample No. (2) grain straight: surface smooth. *Tan.*—Grain straight: surface with small longitudinal furrows and occasional splinters. [*Vide* Plate I, Nos. 25 and 26.]
2·67		5	2	3	...	3·33		...	3		

Details of Splitting Tests with various Indian

				RELATIVE SPLIT											
				GREEN WOOD.								Dry			
				Radial.				Tangential.				Radi			
Order of fissibility.	Name.	Sample Number.	Locality.	1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
38	Cedrela Toona	...	Dehra Dun	8	14	45	22·33	5	15	3	7·67	5	4	9	...
39	Terminalia tomentosa.	1	Do.	5	11	9	8·33	4	6	8	6	7	5	13	...
		2	Mandla, Central Provinces.	..	...	...	...	...	...	...	...	4	...	...	...
		3	Dehra Dun	..	...	...	...	...	...	...	...	2	3	...	...
40	Bridelia retusa	...	Mandla, Central Provinces.	...	...	...	...	...	...	...	...	8	...	...	...
41	Grewia vestita	...	Dehra Dun	16	9	9	11·33	4	4	3	3·67	5	4	11	...

Woods arranged in order of Fissibility—continued.

TING FORCES.											
WOOD.								GENERAL AVERAGE, RADIAL AND TANGENTIAL.			
al.		Tangential.						Green wood	Dry wood		REMARKS.
Average of columns 13, 14 15 and 16.		1	2	3	4	Average of columns 19, 20, 21 and 22.					(NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
For separate samples.	For all samples of same species.					For separate samples.	For all samples of same species.	Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
17	18	19	20	21	22	23	24	25	26	27	28
...	6	3	2	...	...	...	2·5	15	...	4·25	*Rad.*—Grain varies much, being sometimes very cross-grained, withdeep rough longitudinal furrows, and sometimes nearly straight, with only slight furrowing. *Tan.*—Grain straight; surface smooth. [*Vide* Plate I, Nos. 7,8 and 9.]
8·33	5·67	4	4	5	...	4·33	3·6	7·17	6·33	4·63	*Rad.*—Straight to slightly cross-grained: surface varies from fairly smooth to somewhat furrowed, usually with longitudinal splintering. *Tan.*—Grain straight: surface fairly smooth to finely furrowed, with longitudinal splintering. [*Vide* Plate I, Nos. 27 and 28.]
4		...	...	...	...	...		...	4		
2·5		2	3	...	...	2·5		...	2·5		
...	8	2	...	...	...	...	2	...	...	5	*Rad.*—Cross-grained: surface rough, with longitudinal furrows and splintering. *Tan.*—Surface fairly smooth, but the specimen was somewhat knotty.
...	6·67	3	4	4	...	...	3·67	7·5	...	5·17	*Rad.*—Straight to slightly cross-grained and sometimes finely wavy. Surface varies according to grain from smooth to finely wavy. *Tan.*—Straight and smooth to finely wavy. [*Vide* Plate II, Nos. 45 and 46.]

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT											
				GREEN WOOD.								DRY			
				Radial.				Tangential.				Radi			
				1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
42	Casuarina equisetifolia.	...	Dehra Dun	...	...	...	...	...	...	...	...	6	7	5	...
43	Quercus semecarpifolia.	1	Jaunsar, United Provinces.	...	...	...	...	...	...	..	...	9	10	...	...
		2	Do.	...	...	...	...	...	...	...	...	3	3	...	...
		3	Do.	...	...	...	...	...	...	...	...	5	5	3	..
44	Bombax malabaricum.	1	Dehra Dun	6	5	5	5·33	2	3	5	[illegible]·33	2	3	2	...
		2	Do.	...	...	..	...	...	...	...	...	5	6	7	...

Woods arranged in order of Fissibility—continued.

TING FORCES.											
WOOD.								GENERAL AVERAGE, RADIAL AND TANGENTIAL.			REMARKS.
al.		Tangential.						Green wood.	Dry wood.		(NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
Average of columns 13, 14, 15 and 16.						Average of columns 19, 20, 21 and 22.					
For separate samples.	For all samples of same species.	1	2	3	4	For separate samples.	For all samples of same species.	Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
17	18	19	20	21	22	23	24	25	26	27	28
...	6	4	5	...	...	...	4·5	...	...	5·25	*Rad.*—Surface rough and somewhat wavy owing to the curving of the fibres round the large medullary rays. *Tan.*—Surface rough and pitted where the large medullary rays are broken across.
9·5	5·43	7	6	...	...	6·5	5·67	...	8	5·55	*Rad.*—Grain straight to wavy: surface slightly furrowed and splintering much longitudinally, medullary rays not conspicuous. *Tan.*—Grain straight to wavy surface fairly smooth to slightly ridged longitudinally. [*Vide* Plate II, Nos. 51 to 54.]
3		3	8	...	...	5·5		...	4·5		
4·33		7	3	...	...	5		...	4·66		
2·33	4·17	1	2	1	...	1·33	1·67	4·33	1·83	584	*Rad.*—Sample No. (1) Grain straight: surface furrowed longitudinally, splintering much when split green but little when split dry. Sample No. (2). Grain rather oblique: surface very rough owing to the soft oblique fibres being cut and torn across. *Tan.*—Grain straight: surface smooth. (*Vide* Plate II, Nos. 67 and 68.)
6		1	3	1	...	2		...	4		

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELTIVE SPLIT — GREEN WOOD. — Radial. — 1	2	3	Average of columns 5, 6 and 7.	Tangential. — 1	2	3	Average of columns 9, 10 and 11.	DRY — Rad — 1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
45	Albizzia stipulata.	...	Dehra Dun	13	18	17	16	3	4	4	3·67	8	7	9	...
46	Holoptelea integrifolia.	...	Dehra Dun	...	...	...	...	...	...	...	...	7	13	8	...
	Gmelina arborea.	...	Do.	...	...	...	...	...	...	...	...	10	4	5	...

Woods arranged in order of Fissibility—continued.

TING FORCES.

WOOD.								GENERAL AVERAGE, RADIAL AND TANGENTIAL.			
al.		Tangential.						Green wood.	Dry wood.		REMARKS.
Average of columns 13, 14, 15 and 16.						Average of columns 19, 20, 21 and 22.					(NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
For separate samples.	For all samples of same species.	1	2	3	4	For separate samples.	For all samples of same species.	Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
17	18	19	20	21	22	23	24	25	26	27	28
...	8	3	5	4	...	...	4	9·83	.	6	*Rad.*—Straight-grained to slightly cross-grained with longitudinal furrowing and splintering. *Tan.*—Grain straight: surface fairly smooth, but with fine longitudinal furrows and sometimes fine splintering.
...	9·33	3	3	3	..	...	3	...	...	6·17	*Rad.*—Cross grained: surface with longitudinal furrows. *Tan.*—Grain straight: surface fairly smooth.
...	6·33	3	7	8	...	...	6	...	...	6·17	*Rad.*—Fairly straight-grained to very cross-grained: surface fairly smooth to deeply furrowed, the cross-fibres being torn out. *Tan.*—Grain straight except specimen No. (3), which was a bad specimen with oblique grain and a knot. Surface fairly smooth, splintering longitudinally.

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT											
				GREEN WOOD.								DRY			
				Radial.				Tangential.				Radi			
				1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
48	Anogeissus latifolia.	...	Dehra Dun	32	62	16	36·67	14	4	5	7·67	19	3	5	...
	Ægle Marmelos	...	Dehra Dun	...	...	...	...	...	...	...	...	3	11	8	...
50	Gardenia gummifera.	...	Raipur, Central Provinces.	...	...	...	...	...	...	...	...	8	...	...	...
51	Quercus dilatata.	1	Jaunsar, United Provinces.	...	...	...	...	...	...	...	...	7	9	...	...
		2	Do.	...	...	...	...	...	...	...	...	4	4	...	...

Woods arranged in order of Fissibility—continued.

TING FORCES.

Wood.								General average, radial and tangential.			Remarks.
al.		Tangential.						Green wood.	Dry wood.		
Average of columns 13, 14, 15 and 16.						Average of columns 19, 20, 21 and 22.					(NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure).
For separate samples.	For all samples of same species.	1	2	3	4	For separate samples.	For all samples of same species.	Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
17	18	19	20	21	22	23	24	25	26	27	28
...		3	3	5	...	...	3·67	22·17	...	6·33	*Rad.*—Grain and surface coarsely and excessively wavy to finely wavy or almost straight. *Tan.*—Finely wavy to nearly straight. *Vide* Plate I, Nos. 16, 17 and 18.
...	7·33	8	4	4	...	...	5·33	...	...	6·33	*Rad.*—Grain and surface somewhat wavy, with longitudinal splintering. *Tan.*—Similar. The waviness is due to the presence of small knots and dormant buds.
...	8	5	...	...	...	...	5	...	...	6·5	*Rad.*—Surface uneven and indented in the manner characteristic of the Gardenias. *Tan.*—Similar, but not so deeply indented.
8 4	6	3 14	3 11	... ...	... ...	3 12·5	7·75	... ...	5·5 8·25	6·87	*Rad.*—Grain fairly straight to somewhat curly, but not cross-grained: surface rather rough, splintering much longitudinally. *Tan.*—Grain wavy: surface pitted where the large medullary rays are broken across. Both the tangential splitting tests with sample No. (2) were unsatisfactory, as the specimens had knots which affected the straightness of the grain and increased the difficulty of splitting.

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT											
				Green Wood.								Dry			
				Radial.				Tangential.				Radi			
				1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
52	Dalbergia Sissoo.	1	Dehra Dun .	34	34	32	33·33	6	3	2	3·67	20	11	24	...
		2	Do. .	...	...	...	...	...	...	...	...	7	7	11	...
53	Pterospermum acerifolium.	...	Dehra Dun .	...	...	...	...	...	...	...	...	9	12	23	...
	Calophyllum spectabile.	...	Andamans .	...	...	...	...	...	...	...	...	10	12	22	...
55	Shorea robusta	1	Dehra Dun .	26	22	26	24·67	2	3	2	2·33	10	11	26	...
		2	Do. .	...	...	...	...	...	...	...	...	42	6	6	...

Woods arranged in order of Fissibility—continued.

TING FORCES.											
WOOD.								GENERAL AVERAGE, RADIAL AND TANGENTIAL.			REMARKS. (NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
al.		Tangential.						Green wood.	Dry wood.		
Average of columns 13, 14, 15 and 16.						Average of columns 19, 20, 21 and 22.					
For separate samples.	For all samples of same species.	1	2	3	4	For separate samples.	For all samples of same species.	Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
17	18	19	20	21	22	23	24	25	26	27	28
18·33 8·33	13·33	2 3	2 2	3 4	... ...	2·33 3	2·67	18·33 ...	10·33 5·67	8	*Rad.*—Cross-grained: surface with much deep longitudinal furrowing. *Tan.*—Grain straight: surface fairly smooth. [*Vide* Plate I, Nos 14 and 15.]
...	14·67	3	4	3	...	...	3·33	...	...	9	*Rad.*—Cross-grained: surface with deep longitudinal furrows where the cross-fibres are torn out. *Tan.*—Grain straight: surface smooth. [*Vide* Plate I, Nos. 29 and 30.]
...	14·67	3	3	4	...	...	3·33	...	...	9	*Rad.*—Grain wavy and cross-grained: surface indented with large longitudinal furrows. *Tan.*—Grain somewhat wavy: surface much smoother than on the radial section, but slightly furrowed.
15·67 18	16·83	2 2	2 2	2 1	... ...	2 1·67	1·83	13·5 ...	8·83 9·83	9·33	*Rad.*—Very cross-grained: surface with deep longitudinal furrows; more splintering when split green than when split dry.—*Tan.*—Grain straight: surface fairly smooth. [*Vide* Plate I, Nos 21 and 22.]

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT											
				Green Wood.								Dry			
				Radial.				Tangential.				Radi			
				1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
56	Chloroxylon Swietenia.	...	Mandla, Central Provinces.	...	...	...	...	...	...	...	...	8	22	...	..
57	Pterocarpus Marsupium.	...	Balaghat, Central Provinces.	...	...	...	...	...	...	...	...	23	24	16	...
58	Bauhinia retusa	...	Dehra Dun	...	...	...	...	...	...	...	...	30	24	18	...
58	Dalbergia latifolia.	...	Balaghat, Central Provinces.	...	...	...	...	...	...	...	...	26	23	...	...

Woods arranged in order of Fissibility—continued.

TING FORCES.											
WOOD.								GENERAL AVERAGE, RADIAL AND TANGENTIAL.			REMARKS. (NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
al.		Tangential.						Green wood.	Dry wood.		
Average of columns 13, 14, 15 and 16.		1	2	3	4	Average of columns 19, 20, 21 and 22.		Average of columns 8 and 12.	For separate samples. Average of columns 17 and 23.	For all samples of same species. Average of columns 18 and 24.	
For separate samples.	For all samples of same species.					For separate samples.	For all samples of same species.				
17	18	19	20	21	22	23	24	25	26	27	28
...	15	7	4	...	...	...	5·5	...	...	10·25	*Rad.*—Very cross-grained : surface very rough, with deep longitudinal furrows. *Tan.*—Grain curly ; surface curved showing on its surface the pattern of the cross fibres. [*Vide* Plate I, Nos. 19 and 20.]
...	21	2	1	2	...	...	1·67	...	...	11·33	*Rad.*—Cross-grained : surface with longitudinal furrows and splintering. *Tan.*—Grain straight, surface flat with fine longitudinal furrows and splintering. [*Vide* Plate I, Nos. 3 and 4.]
...	24	3	3	6	...	...	4	..	...	14	*Rad.*—Cross-grained : surface with deep furrows and much splintering. During splitting the wood splinters off by cracks at right angles to the sides of the wedge. *Tan.*—Grain fairly straight : marked longitudinal splintering on surface. [*Vide* Plate I, Nos. 23 and 24.]
...	24·5	4	3	...	...	...	3·5	..	...	14	*Rad.*—Very cross-grained : surface much furrowed longitudinally. *Tan.*—Grain straight : surface fairly smooth, tending to follow the curve of the concentric cylinders. [*Vide* Plate I, Nos. 10 and 11.]

Details of Splitting Tests with various Indian

Order of fissibility.	Name.	Sample Number.	Locality.	RELATIVE SPLIT											
				GREEN WOOD.								DRY			
				Radial.				Tangential.				Radi			
				1	2	3	Average of columns 5, 6 and 7.	1	2	3	Average of columns 9, 10 and 11.	1	2	3	4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
60	Dalbergia Oliveri.	...	Katha, Upper Burma.	...	...	...	...	...	...	...	..	47	24	...	...
61	Ougeinia dalbergioides.	1	Dehra Dun .	...	...	...	...	...	...	...	...	16	18	220	225
		2	Balaghat, Central Provinces.	...	...	...	...	...	...	...	...	45	24	36	...

Woods arranged in order of Fissibility—concluded.

TING FORCES. — WOOD. — al. — Average of columns 13, 14, 15 and 16. — For separate samples.	TING FORCES. — WOOD. — al. — Average of columns 13, 14, 15 and 16. — For all samples of same species.	Tangential. — 1	Tangential. — 2	Tangential. — 3	Tangential. — 4	Tangential. — Average of columns 19, 20, 21 and 22. — For separate samples.	Tangential. — Average of columns 19, 20, 21 and 22. — For all samples of same species.	GENERAL AVERAGE, RADIAL AND TANGENTIAL. — Green wood. — Average of columns 8 and 12.	GENERAL AVERAGE, RADIAL AND TANGENTIAL. — Dry wood. — For separate samples. Average of columns 17 and 23.	GENERAL AVERAGE, RADIAL AND TANGENTIAL. — Dry wood. — For all samples of same species. Average of columns 18 and 24.	REMARKS. (NOTE.—*Rad.* refers to the radial and *Tan.* to the tangential fissure.)
17	18	19	20	21	22	23	24	25	26	27	28
...	35·5	2	2	...	...	...	2	...	...	18·75	*Rad.*—Very cross-grained: surface with numerous longitudinal furrows. *Tan.*—Grain straight: surface fairly smooth, tending to follow the curve of the concentric cylinders. Manner of splitting very similar to that of *D. latifolia*. [*Vide* Plate I, Nos. 12 and 13.]
119·75 35	83·43	4 6	3 11	11 4	4 ...	5·5 7	6·14	... ...	62·37 21	44·78	*Rad.*—Very cross-grained, with tough fibres: surface very rough, with deep longitudinal furrows and splintering. Owing to the stiffness of the fibres the wedge repeatedly sprang out of the cleft during splitting. *Tan.*—Grain fairly straight: surface fairly smooth, with fine longitudinal furrows and occasional fine splinters. [*Vide* Plate I, Nos. 1 and 2.]

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
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VOL. II PART III

THE

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By D. O. WITT,
Deputy Conservator of Forests, Central Provinces

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By RAO SAHIB M. RAMA RAO,
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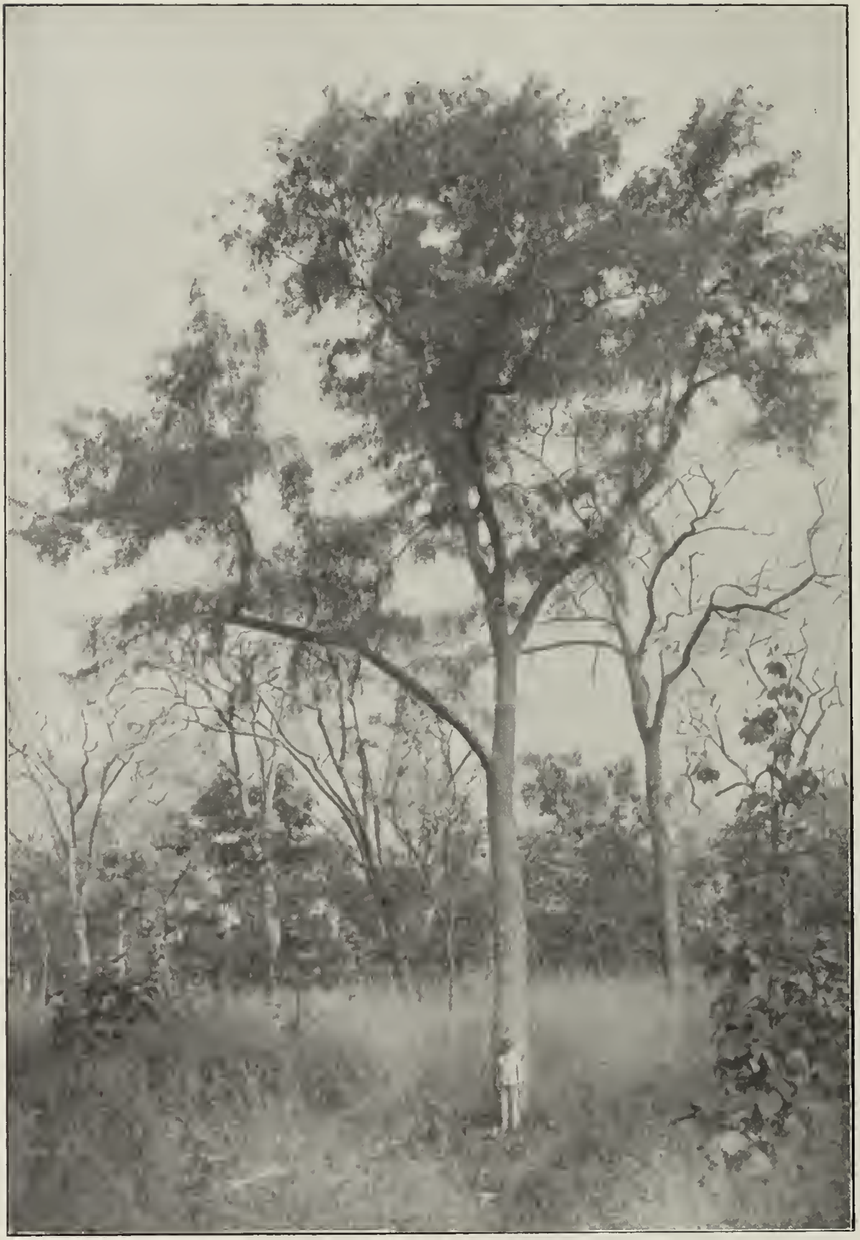

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HARDWICKIA BINATA (ANJAN) ON SANDSTONE, PUNASA RESERVE, NIMAR DIVISION, C. P.
HEIGHT 70 FEET, GIRTH 6′ 7″.

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PART I.—SYLVICULTURAL HABITS OF THE SPECIES.

I.—References.

The Flora of British India, J. Hooker, Volume II, page 270.

The Forest Flora of North-West and Central India, D. Brandis, page 162.

Indian Trees, D. Brandis, page 250.

A Manual of Indian Timbers, J. S. Gamble, page 276.

The Forest Administration Report of the Berar Circle, Central Provinces, 1903-04, page 11.

The Indian Forester, Volume XXIX, pages 517—527.

The Indian Forester, Volume XXX, page 123.

The Indian Forester, Volume XXXI, pages 105 and 106, 380—382 and 695—698.

The Indian Forester, Volume XXXV, pages 376—381.

II.—Description of the Species.

A large deciduous tree. Bark 1 inch thick, dark grey, rough with irregular vertical cracks, exfoliating in narrow flakes. Wood extremely hard; sapwood small, yellowish white; heartwood dark reddish-brown, streaked with purple, usually in concentric wavy lines, close and fine grained. Annual rings not very distinct, but with a good lens can frequently be made out by the numerous pores filled with resin at the inner edge of the ring.

The proportion of sapwood to heartwood varies with the diameter of the tree, but measurement along the radii of a number of specimens gave the following proportions for bark, sapwood, and heartwood of trees $4\frac{1}{2}$ feet in girth :—

Bark	15 per cent.
Sapwood	25 ,,
Heartwood	60 ,,

Average weight of the wood 82 lbs. per cubic foot, but wood from the Upper Godaveri appears generally to be lighter. Leaves bifoliate; leaflets sessile, entire, obtuse, obliquely ovate or semi-cordate, with 4-5 arcuate merves. Stipules small, cordate, caducous. Flowers greenish-yellow, on long slender racemes, arranged in axillary or terminal panicles; pedicels shorter than flowers; bracts minute, caducous. Ovary oblong, style ascending with a large peltate stigma. Pod lanceolate, 2-3 inches long, with parallel longitudinal veins, a solitary seed near the top.

III.—Utility.

The dark reddish-brown heartwood is used for house posts and bridges, and for ornamental work, being very durable. It is liable to split, but does not warp. It has been used for sleepers on the Rajputana Malwa Railway. Sleepers buried at the Forest College, Dehra Dun, when dug up in 1893, after 7 years in the ground, were found still perfectly sound in every respect.

The bark yields a valuable fibre, and the leaves are much relished by cattle for fodder. In Berar and South India the trees were formerly much pollarded for cattle fodder.

IV.—Distribution.

(1) GENERAL.

In the dry forests of South and Central India, but not everywhere, extending northwards as far as the Banda District of the United Provinces. Generally gregarious in patches of greater or less extent. In South India its chief localities are :—in Godaveri in the forests round Bhadrachalam; in Kistna in the great Bollapilli Reserve; in Anantapur in the Muchukota forest; in Bellary at Malpangudi; also in Cuddapah and Kurnool. Further south it is found on both banks of the Cauvery in Salem District and on the Balarangams, and at Hasanur and Gazalhati in Coimbatore.

In Central India the tree is found in Chanda, parts of Berar, Khandesh, Nimar, Hoshangabad, and Indore State as far north as Mhow. The strangely local nature of the distribution of this species is but one of its many interesting peculiarities, and much local knowledge will have to be gathered together and put on record, before a satisfactory explanation is forthcoming. Soil and climate—usually the most powerful factors in determining the limits of a species—do not supply in this case the solution to the question, though the former affects the quality of the growth to a very great extent.

No better evidence could be adduced than a study of the distribution of the Anjam in the Nimar District of the Central Provinces, with which the writer has had four years' experience. We propose to deal with the point at some length, since a just appreciation of this phenomenon is necessary in considering the other sylvicultural peculiarities of the species, and any theories for the successful treatment of it, whether these theories be based on ascertained facts or on mere deductions from general observations.

In order to draw attention to this peculiarity of the Anjan, it is necessary in the first place to describe the physical features and the geology of the Nimar District.

(2) PHYSICAL FEATURES OF THE NIMAR DISTRICT.

Almost through the centre of the district, from west to east, runs a branch of the Satpuras forming the watershed between the Nerbudda river on the north and the Taptee on the south. Practically the whole of this ridge is Government reserved forest. Between this range of hills and the Nerbudda river lies the town of Khandwa in a broad and fertile valley. The drainage from the central ridge to the north is diverted from its direct course by another low and irregular ridge constituting the forests of the Khandwa Range. This particular block will be alluded to again later on. North of this ridge, and bordering the Nerbudda river, is a strip of broken and hilly ground, from 3 to 6 miles wide, constituting the forests of the Punasa Range. On the north bank of the river, and to the east is situated the Chandgarh Range, on the continuation of the hills constituting the Punasa Range.

Along the southern face of the main central branch of the Satpuras runs the Taptee. South of this river rises a higher ridge,

forming the southern face of the Satpuras and separating Nimar from the Berar plain. These hills are the highest in the district, and constitute the forests of the Burhanpur Range. A deep fertile valley separates these two branches of the Satpuras, except for the isolated hill of Samardeo.

A reference to the attached sketch map will clearly show these main physical features.

(3) Geology of the Nimar District.

With the exception of a fringe of ground along both banks of the Nerbudda in the most northern part of the district, the underlying rock is trap. On the surface the trap is more or less decomposed into moorum, and in the valleys forms a fairly deep soil, but on the hills the soil is shallow, and stretches of bare sheet rock are frequent.

The excepted tract is composed of Vindhyans, consisting of sandstones, conglomerates, and shales, with small outcrops of granite, schists, and gneisses of the Archæan system, and lametas of the Cretaceous system. A considerable portion of the Punasa and Chandgarh Ranges consists of hard, almost crystalline Vindhyan sandstones, very difficult of disintegration, and consequently yielding a shallow soil.

On the other hand, the outcrops of granite and gneiss, as well as the cretaceous limestone-bearing transition rocks of the Chandgarh Range, are of loose structure and often conglomeritic. They, therefore, disintegrate more easily, and result in a deeper and richer soil.

(4) Distribution and Composition of Anjan Forests in Nimar.

Now let us see how the configuration of the ground and the underlying rock affects the distribution of the Anjan. We will first take the main branch of the Satpuras running from west to east. On the extreme west we find the Anjan scattered and fairly plentiful, but proceeding east it becomes less so, until we reach the railway at Mandwa where it practically vanishes, hardly a single tree being found throughout the whole of the ridge east of the railway.

Isolated Anjan are found on Samardeo, and it is fairly common at the western extremity of the ridge separating Nimar from the Berar plain. It does not grow to any great size in these areas. Proceeding to the areas north of the main central ridge, we find the low and undulating hills of the Khandwa Range fairly stocked with Anjan, and to the extreme west of this range, and extending almost up to the Nerbudda, we find a

peculiar type of Anjan growth, *viz.*, isolated blocks of practically pure Anjan in the pole stage, growing closely and thickly together. Old mature trees are few and far between, and where found are of small dimensions, and have invariably, at some time or other in their life, been pollarded. That the present pole growth is the natural regeneration of a previously existing Anjan forest goes without saying, but the manner of its formation is a subject of much speculation. These Anjan areas appear to be a continuation from the south, northwards, of the areas already referred to at the western end of the main central branch of the Satpuras.

Perhaps even more extraordinary are the areas outside the blocks of Government forest now referred to. The ground is for the most part undulating, and much is unfit for cultivation. The Anjan here holds its own tenaciously, in spite of all that is done by grazing and felling to exterminate it. Its feathery green foliage is a peculiar feature of the landscape in the hot season, long after all other species are leafless. The average height of a mature Anjan tree throughout these areas may be put at 40 feet, and its girth at 3 feet.

We now come to the strip of broken and hilly ground bordering the Nerbudda, and extending to the extreme north-east of the district, constituting the Punasa and Chàndgarh Ranges. We find the Anjan throughout this area, but always mixed with other species, never pure, the proportion of Anjan to other species being seldom more than 5 per cent. The patches of pure pole Anjan previously referred to are never found in this area, though natural regeneration is by no means absent. It must be remembered that here we are for the most part off the trap, and in place thereof have Vindhyan sandstones, conglomerates, granite, schists, and limestone.

Most remarkable is the development of the Anjan in this area. Nowhere else in the district does the tree develop such proportions, both as regards height growth and girth. Mature trees with a height of from 80 to 100 feet and a girth of from 6 to 10 feet are by no means uncommon, with a clean cylindrical bole of from 40 to 50 feet.

Having now described the distribution of the Anjan with reference to the physical features and geology of the district, it remains to be seen what sylvicultural facts governing this distribution can be deduced therefrom. This brings us to a consideration of the "Locality," which, as every forester is aware, is the sylvicultural term employed to denote the active agencies of soil and climate in their relation to, and combined effect on, forest vegetation.

V.—Locality.

(1) Soil Requirements.

(a) *Depth of Soil.*

The Anjan, as will be described further on, develops a moderately long tap-root, and for this reason prefers a deep soil into which the tap-root can easily penetrate. At the same time it cannot be said to be exacting in this respect, for it is commonly found on trap rock where the surface soil is very shallow, and it thrives particularly well on the hard crystalline Vindhyan sandstones, which disintegrate with difficulty and have as a consequence a shallow soil covering. On this latter formation it would appear that the chemical composition of the soil and underlying rock plays the most important part, for it has been noticed that whereas the forest growth on this formation is generally of the Salai (*Boswellia serrata*) type, and teak is scanty and of poor quality, Anjan grows to its very best. The trees are very scattered in such areas, and there is a notable absence of natural regeneration, but such trees as do establish themselves grow to very large dimensions. The fact that the Anjan can thrive on shallow soils is also very probably due to the extraordinary power of the tap-root, which seems to be able to bore its way even through hard rock down to a permanent water-supply.

(b) *Porosity of the Soil.*

A porous soil with a well-fissured underlying rock is required for the best development of Anjan.

This statement must not be thought to contradict what has been said in the preceding paragraph regarding the development of Anjan on the hard crystalline Vindhyan sandstones. True, the development of individual trees cannot be bettered on this formation, but on the other hand on the loose-structured formations in the Punasa and Chandgarh Ranges of the Nimar Division, on the conglomerates and shales, we have not only an equally good individual development, but what is of more importance, ample natural regeneration in addition. For this reason a porous soil with a well-fissured underlying rock is preferable to a firm soil overlying a hard non-disintegrating rock. Nowhere on the trap formation, with as a rule an impervious stratum a short distance below the surface, does the Anjan develop to anything like the size it attains on the more loose-structured formations.

(c) *Degree of Moisture in the Soil.*

We know very little regarding the absolute requirements of the species in this respect, but one thing is certain,—the Anjan requires a constant and permanent supply of water while young, which supply it takes up through the tap-root it develops. By this means alone is it able to survive the months of dry and hot weather, during which there is no rainfall and the plant is exposed to scorching dry winds, causing rapid evaporation from its leafy surfaces. On the other hand, from the sapling stage upwards, which, so far as our knowledge goes at present, means from the age of about 15 years, the Anjan can put up with very little moisture, and is essentially a drought-resisting species. This was very noticeable in Nimar during the droughts of 1901 and 1904. Whereas following these droughts such species as *Tectona grandis*, *Terminalia tomentosa*, *Lagerstrœmia parviflora*, *Mangifera indica*, *Buchanania latifolia*, suffered severely all over the Division, not only coppice being affected, but also mature trees, in the case of Anjan no damage whatever was done, even on the driest soils.

(d) *Chemical Composition.*

From what has gone before we can safely say that the Anjan prefers sandstones, conglomerates, gneiss, limestone, and generally rock formations which produce a sandy loam as soil for the roots, rather than the stiffer and more clayey soil changing into moorum which overlies the trap. The former soils afford a better drainage, the underlying rock being as a rule of looser structure, and this is no doubt a factor favouring the Anjan, though, as already pointed out, individual trees develop equally well on an underlying rock of much closer and harder texture, provided that rock is a sandstone.

Mr. E. D. M. Hooper, Conservator of Forests, Madras Presidency, writes in a letter to the Conservator of Forests, Berar Circle, Central Provinces, regarding the soils most favourable for Anjan, as follows :—

> "In the Ahiri Zamindari to the south of the Bhimaram reserve, Anjan was found in 1881 over a restricted area, a pure forest, the stems being strangely uniform, varying in girth from 5 to 6 feet, and in height from 40 to 60 feet, with clear straight bole.
>
> "*The soil was a quartzose red gravel, crunching under foot, and I have generally observed that wherever Hardwickia is prevalent, this soil occurs.*"

Again :—

> "As regards its distribution, we find it occupying clearly defined areas on the *rocky quartz soils* of Bellary and Anantapur, and the *sandstones and shales* of the Palnad in Kistna."

Mr. E. M. Crothers, Forest Ranger, writes in the *Indian Forester* for July 1905, under the heading "Sylvicultural Notes on Hardwickia binata," the following :—

> "I have seen Hardwickia on all aspects and doing very well so long as the soil is inclined to be *sandy* and deep ; the underlying rock in all the reserves here is chiefly *quartzite, which yields a reddish-yellow gritty soil* on which the growth of grass and other vegetation is not very profuse, and this seems to be the soil favoured by Hardwickia."

These formations are very similar to those of the Punasa and Chandgarh Ranges of the Nimar District already referred to as producing the best growth of Anjan.

On the other hand it is very commonly found on trap, but here we come across a peculiar characteristic—it is by no means universal on the trap.

To come back again to that main central branch of the Satpuras. The whole of it is trap formation, most of it with a very shallow soil-covering, bearing the poorest forest growth, and this is particularly noticeable over the western portion of the ridge where the Anjan is found ; yet there is a definite limit where the railway crosses this ridge from south to north. These is no obvious reason for this phenomenon. The soil is no poorer to the east, in fact on the extreme east in the Khibhit Range the soil is as a rule much deeper, and some of the best teak forest is found here. Climate, aspect, rainfall, none of these can be said in this prescribed area to affect the question.

There should be no difficulty in collecting information regarding the distribution of Anjan in other districts, and carefully comparing and tabulating the information obtained. This, however, is a work that can only be carried out by the Imperial Sylviculturist at the Dehra Dun Research Institute. Such results would very likely throw further light upon the subject, but for the present, at any rate, we must leave it at this, that the peculiar gregarious nature of the Anjan prescribes in an unknown manner the limits of the species on trap rock.

(2) CLIMATE.

(*a*) *Rainfall.*

The Anjan prefers a dry climate. The average annual rainfall in the localities peculiar to the species varies from 10 to 60 inches. In South India, in the localities mentioned under "Distribution," it enjoys, for the most part, a rainfall of from 10 to 30 inches. In the Central Provinces it is found where the average rainfall is from 20 to 60 inches. It appears to thrive best with a rainfall of from 20 to 40 inches as obtains in Nimar, where, so far as the Central Provinces are concerned, the best growth occurs.

(*b*) *Heat and Aspect.*

Except when quite young, Anjan can stand a great deal of heat, and at all stages a considerable amount of cold. Growing as it does in the dry hot regions of Central India, it frequently has a shade temperature as high as 112° to put up with during the months of April and May.

The following average mean maximum and minimum temperatures during selected months, as recorded at Khandwa since 1875, will give a general idea of the temperature suitable to the growth of Anjan :—

	Maximum.	Minimum.	Mean.
January	84°	52°	67·5°
May	106·5°	81°	93°
July	87·5°	75°	80·5°

Frosts not infrequently occur in these regions in low-lying localities, though as a rule they are not severe. No instance has come to our knowledge of Anjan, either in the seedling, sapling, or mature stage, suffering in the least degree from such frosts.

This, however, is not the opinion of all who have studied the peculiarities of the Anjan. Mr. E. E. Fernandez, late Conservator of Forests, who was for several years in charge of the Nimar Division, wrote as follows in his annual report for 1877-78 :—

> "The Anjan seedlings were slightly cleared of the tall grass weighing down over them. This is all that is necessary as weeding exposes the seedlings too much to the air, and makes them sensitive to drought and *frost.*"

Again, in his report for 1878-79 he wrote :—

"The Anjan germinated very fairly, *but, like the teak, suffered from the effects of frost.* This species, from the sapling stage upwards, is capable of resisting even severe frosts, *but, as was to be expected, the low delicate seedlings barely 6 months old easily succumbed.*"

As stated above, we are quite of a contrary opinion, and feel sure that what Mr. Fernandez took to be the effect of frost was really the effect of drought. This is borne out, moreover, by what he himself wrote many years later, when he had had considerably more experience of the species. On pages 525 and 526, Volume XXIX of the *Indian Forester*, quoting from a letter to the Inspector-General of Forests, Mr. Fernandez says :—

"In the Punasa forests in 1874, when I took over charge of them, I found the most perfect new reproduction wherever there had recently been field cultivation. . . . . . . In October the seedlings began to wither, and by the middle of the hot weather there was scarcely a single one alive, the inability of the tap-roots to penetrate through the dense mass of grass roots was the cause of their death."

No mention at all is made of frost, besides which, the seedlings were noticed to be withering already in October, at least two months before the first frosts occur.

Direct observation on our own part has satisfied us that frost is no enemy of the Anjan seedling. On the 16th January, 1906, we were camped at Kirgaon, where, at the time, the adjoining forest was full of Anjan seedlings in their first year, the result of a prolific seeding in 1905. That night a severe frost occurred, killing all the brinjal and tomato plants in the forest garden, and doing considerable damage to such species as *Terminalia tomentosa*, *Buchanania latifolia*, *Tectona grandis*, and others, as was evident by the blackened and withered branches to be seen when inspecting the forest the following morning. We particularly noted on that occasion the absolute immunity from all damage of the Anjan seedlings. Again on the 6th January, 1908, a similar frost occurred, and the same facts were again observed. It may be added that not only were seedling Anjan immune, but Anjan in every stage of growth.

On the other hand seedling Anjan suffer terribly from excessive heat. Curiously enough it is only at this stage of its career that excessive heat

appears to have any injurious effect on the Anjan. There is little doubt that the holocaust of seedlings, which has been noticed again and again to occur after a good seeding, is due to the excessive heat combined with scorching winds causing too rapid evaporation, the seedling being unable, except under the most favoured circumstances, to replace through its root the moisture lost thereby. Aspect would only appear to be of importance in so far as it modifies the temperature to which seedlings are exposed in the hot weather, and protects them from the scorching dry winds. From notes and observations taken in Nimar, it would appear that aspects between north and south give the greatest protection to Anjan seedlings, and are therefore most suitable to the development of Anjan.

(c) *Light.*

Anjan is on the whole a light demander, and cannot force its way through overhead shade. Even the moderate shade afforded by a mature tree of *Boswellia serrata* is too dense for an Anjan sapling to penetrate through, if once dominated. The very flexible, yielding nature of the leading shoot of an Anjan sapling may also account to some extent for its inability to pierce overhead cover.

At the same time Anjan requires a certain amount of shelter or protection during early youth, though not against light as such. From observations made, we are strongly of opinion that shade as a protection to seedlings during the first three or four years' growth, against the heat and the dry winds of the hot season, is a *sine qua non* in the successful regeneration of Anjan forests.

The observations made were so conclusive on this point, that, although they will be dealt with in greater detail further on, in connection with some experiments relating to the cause of death of Anjan seedlings, it will not be out of place to record that portion which immediately concerns us here. The point under consideration was whether a long growth of grass was injurious to the growth of Anjan seedlings. Two plots measuring 2 square yards, both covered with Anjan seedlings, were marked out alongside each other; from one of them all the grass was removed as soon as it came up, while the other plot was not touched. These plots were examined on January 7th, 1909, the seedlings then being $3\frac{1}{2}$ years old. On the plot kept clear of grass the seedlings, numbering 171, had all, without exception, lost their leaves, and the shoots were in several instances beginning to wither and die. On the plot from which

the grass had not been removed (it was standing on an average $2\frac{1}{2}$ feet high) the seedlings, numbering 83, had, without exception, all their leaves intact and green, and showed no sign whatsoever of withering.

In addition to this, throughout the area where these plots were situated, it was noticed that wherever grass had been removed by cutting and the seedlings exposed to the full light, they had withered or were withering, whereas, under the protection and shade of the long grass, they were all quite green. There can be no other explanation than that the grass over the seedlings acted as a protective covering against the direct rays of the sun, thereby reducing evaporation from the stem and leaves, and lessening the demands on the root for moisture, thus giving the seedlings a better chance of surviving through the dry, scorching months of the hot weather.

VI.—Shape and Development.

A.—SHAPE.

The Anjan is perhaps one of the most graceful of our Indian trees. Its drooping foliage and branches, quivering with the slightest breeze, remind us very much of the European birch tree. During the early part of life the Anjan develops a conical crown ; as it approaches full height the crown extends horizontally, the extremities of the branches drooping slightly downwards.

If allowed to grow up in a free position, so that its natural development is not interfered with, the main stem of the Anjan is found divided comparatively low down, the branching commencing usually at about one-third of the total height from the ground. On the other hand, if grown in a fairly crowded forest where the growing space is limited, it develops a long, cylindrical bole, free from branches. The crown is then reduced to less than one-third of the total height of the tree.

It must be remembered in this connection that the nature of the soil influences the shape of the mature tree, and that shallow and rocky soils produce only short stems, with a tendency to divide early and develop branches.

B.—DEVELOPMENT.

(1) Reproductive Power.

We will commence with the formation, on the mature tree, of the flower which is to produce the seed that will develop into the new indivi-

dual. This may seem like starting at the end, but it is necessary to draw attention to the season of fruiting and seeding, as it is of great importance in the development of the seedling. In describing its life history actual statistics and records will be made use of as far as possible.

(*a*) *Season of Flowering and Fruiting.*

The Anjan then comes into flower during the rains, that is, usually some time in August or September. The fruit is seen on the trees by October, but it is not ripe then, and in fact does not ripen until the following April or May. This is a peculiarity not infrequently met with amongst other species of the same family, such as *Dalbergia Sissoo*, *Pterocarpus Marsupium*, etc.

The seed remains on the tree until May and then falls, being scattered by the winds, which are strong at that season of the year, for a considerable distance from the parent tree, owing to the light nature of the pod which acts as a wing to the seed.

An important point to note here, is that the seed falls when most of the forest fires are over. It therefore suffers very little from this source of danger, so that as a rule every seed which falls from the parent tree is available and ready when the first burst of the monsoon occurs, to do its share in the regeneration of the species.

(*b*) *Periodicity of Flowering and Fruiting, and Quantity of Seed produced.*

When the Anjan flowers and fruits, it produces seed most prolifically, probably more so than any other of our valuable Indian timber trees; but these seedings do not occur annually, nor, when a seeding occurs, is it always of the same intensity. It would not appear that any very definite statistics have been gathered together over a long series of years on this point, but we have collected the following information from the Annual Forest Administration Reports of the Central Provinces and Berar.

The Berar reports were gone through from the years 1876-77 to 1887-88. The only references to be found were :—

(1) 1877-78 was a seed year in Gerumatergaon Reserve (Buldana Division).

(2) 1886-87 was a bad seed year.

The Central Provinces reports were gone through from 1887-88 to 1906-07. The references found were :—

(1) 1898-99 was a bad seed year.
(2) 1899-1900 was a good seed year in Chanda and Nimar.
(3) 1902-03 was a seed year in Gerumatergaon Reserve (Yeotmal Division).

A note of more value than any of the above is made by Mr. Fernandez in the report for 1899-1900, and is worth recording *verbatim* :—

> " It may be convenient to record here the years in which Anjan has seeded in Nimar since the writer of this report joined the service—1874, 1879, 1884, 1889, 1893, 1899."

Here we have some definite figures to go on. To these we can now add the year 1904-05. Accepting the above figures as those of recorded observations, we find that the Anjan reproduces itself by seed almost regularly every five years. From 1874 to 1904 there were in Nimar seven good seed years, and in only one year, *i.e.*, in 1893, was the five-year period deviated from.

The actual year in which a seeding takes place is not, however, necessarily the same in two localities, and it may vary within very prescribed limits. To take a case in point, we have the year 1877-78 as a seed year in the Gerumatergaon Reserve of the Yeotmal Division of Berar, and again the year 1902-03. We shall probably not be far wrong if we fit in the intervening seed years as 1882, 1887, 1892, and 1897, and the fact that 1902 was recorded as a seed year lends strength to this supposition. It will be seen that this cycle of seed years comes in between that recorded for the Nimar Division. The Yeotmal and Nimar Divisions are no doubt some distance apart, but to take a more prescribed area we may mention that this year (1908) none of the Anjan in the Khandwa or Punasa Ranges of the Nimar Division seeded, while all the Anjan trees planted along the roads in the Civil Station of Khandwa, and there are a considerable number, flowered and seeded most profusely.

(c) *Effect of Drought on Seeding.*

It is a well established fact that a year of drought often induces profuse seeding. This frequently occurs with the bamboo *Dendrocalamus strictus*, but it would also appear to be the case with the Anjan. Writing in the Forest Administration Report for 1899-1900,

Mr. Fernandez says:—"Similarly, the drought was the immediate cause of the seeding, always gregarious, of the Anjan."

We certainly have the following facts to uphold this opinion. The rains of 1896, 1899 and 1904 were very scanty throughout the Province, while on two of these occasions, *viz.*, 1899-1900 and 1904-05, good seedings occurred in Nimar. Again, the rainfall as recorded at Khandwa during 1907 was only 17 inches, as against a normal average of 30 inches. May not this have had something to do with the abundant seeding of the Anjan planted along the roads in the civil station as already mentioned?

(2) THE SEEDLING.

(*a*) *Development during First Year.*

We have described the process and periodicity of seeding of the mature tree, and have reached the stage where the seed lies scattered on the ground in the early days of June, waiting for the rain which is to quicken it into life.

We will now continue the story, making use of actual observations to emphasize our facts.

In May 1908, the seed from the Anjan trees planted along the road running past the front of our bungalow in Khandwa was scattered by the wind in large quantities over an open space of compound. The soil here consists of a dry, sandy loam, varying in depth from 6-18 inches, followed by hard moorum soon passing into solid trap rock. The first shower of rain fell on the 13th June, followed by over one inch on the 16th, and smaller amounts on the 17th and 20th.

For easy reference the tables of rainfall for the months of June and July 1908, as recorded at Khandwa, are here appended, as we shall frequently have to refer to them.

Table of Rainfall at Khandwa during June and July 1908.

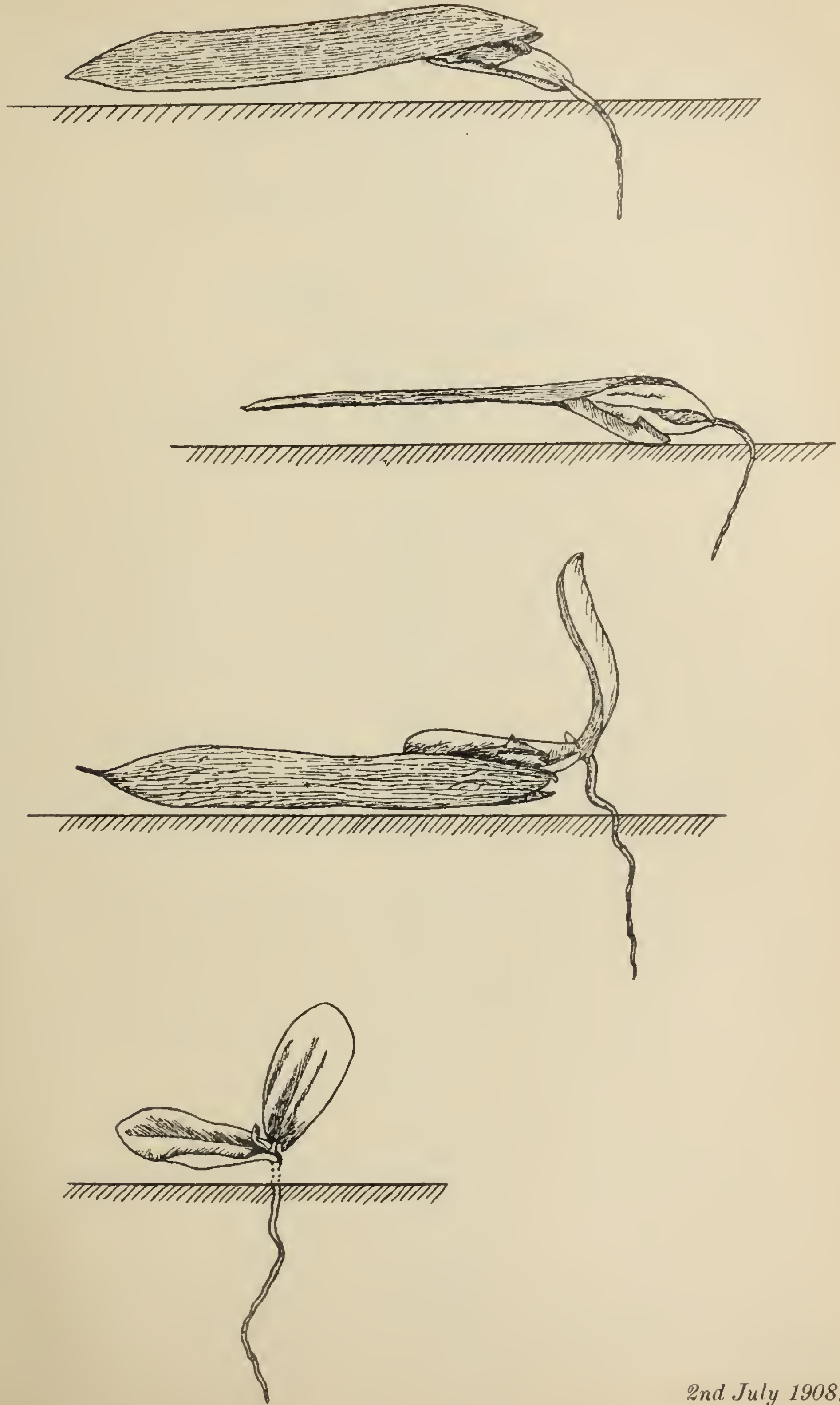
JUNE.

Date	1—12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Amount of rain in inches .	*Nil*	·06	..	..	1·05	·21	..	..	·10	..	..	..	..	..	·61	1·28	1·0	·27	1·22

JULY.

Date . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Amo int of rain in inches .	1·31	..	·18	·08	·02	·25	·15	·02	·13	·50	·62	22	·23	·03	·02	..
Date	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	..
Amount of rain in inches .	·03	..	·06	·05	·15	..	..	..	..	..	..	·60	·82	·28	*Nil*	..

Fig. I.



2nd July 1908.

Fig. II.

Total length of root = 5·75 in.

8th July 1908.

Fig. III.

Total length of root = 9·80 in.

1st Aug. 1908.

(*i*) *Germination.*—The seed lay on the ground during these preliminary showers, but to all outward appearance was not affected thereby. Then came nearly a week of dry hot weather, until on the 26th the rain began again in earnest. Up to this date the seeds had shown no signs of germination, but as a matter of fact they had been taking in the moisture, and the seed was swelling within its seed coats, and preparing itself for further development. Then came six days of continuous rain, during which germination was in active progress, with the result depicted in Fig. I.

This figure represents the stage of development on the 2nd July. The cotyledons are seen bursting or already having burst out from the seed coats, and the radicle well on its way towards forming a tap-root. Let us now turn to Fig. II, which shows us the development a week later—on the 8th July. A reference to the table of rainfall will show that there was continuous rain, though light, between the 2nd and 8th July. The soil, however, was well saturated with moisture, and development was very rapid. The tap-root is already 5·75 inches in length, and two leaves are almost fully formed. It should be here noted that the examples taken were typical of the hundreds of seedlings that were germinating all round, and that no exceptionally developed specimens were chosen.

We will now pass over an interval of three weeks, which brings us to August 1st. Rain fell in small quantities every day except on the 16th, 22nd to 27th, and 31st. Our typical seedling has now developed into a specimen as depicted in Fig. III. Four leaves are fully developed, and there is the beginning of a fifth.

(*ii*) *Development of the tap-root.*—The tap-root is, however, the point that interests us most. That in Fig. III was found to be 9·80 inches in length. For purposes of comparison eight typical seedlings were dug up, with the results shown below :—

Serial No.	Depth below the surface at which hard moorum was met with.	Length of tap-root in inches.	REMARKS.
1	8 inches	9·80	Fig. III.
2	8 ,,	8·38	Incomplete, tip broken.
3	8 ,,	11·33	,, ,, ,,
4	8 ,,	9·20	
5	8 ,,	9·64	Last 2·28 inches were in hard moorum which was with difficulty broken away.
6	10 ,,	11·15	
7	16 ,,	16·10	
8	16 ,,	6·51	Fig. IV. At 2 inches the root met an obstruction of a piece of broken tile, and divided into two branches. Soil mixed with stones and pieces of broken tile.

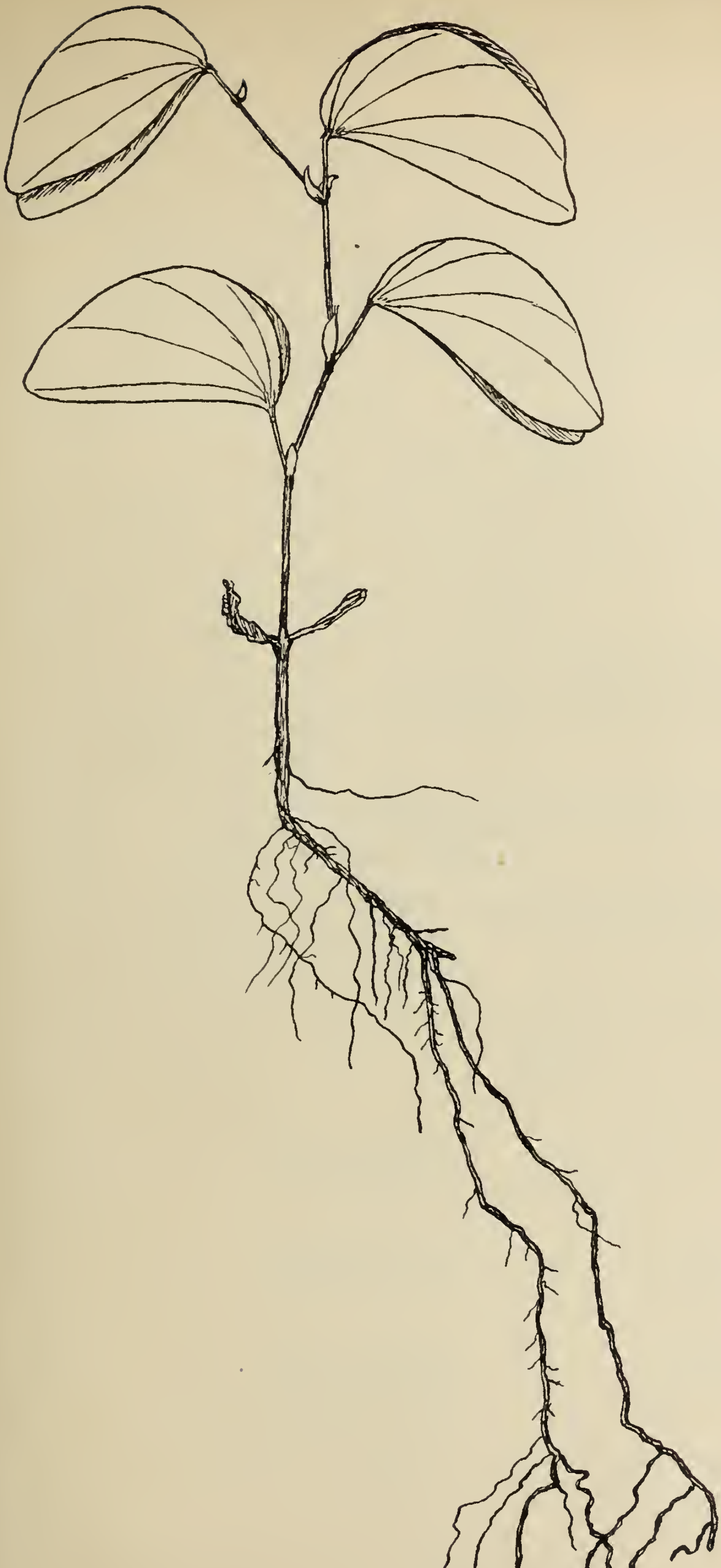
The extraordinary power of the tap-root in be ng able to pierce through what appeared to be almost solid rock was the most noticeable feature in the above experiment.

Fig. IV is of interest as showing the manner in which the tap-root avoided and worked round obstacles which it could not pierce. The breaking up into two main branches is exceptional, and was only brought about by the stony nature of the soil.

On September 1st, that is to say, a month later, we again examine our seedlings. Rain has been neither excessive nor deficient. The first thing that strikes us is that practically no further development has taken place above ground, while below ground the tap-root has only made an appreciable advance where the soil is so deep that growth in length is easily accomplished. Otherwise only a slight thickening of the tap-root is noticeable.

In exceptional cases a difference is seen, and it will be of interest to quote an example. A particularly healthy and well developed seedling was dug up. The part above the ground measured 5½ inches, and had nine leaves developed (compare this with Figs. III and IV), but the length of the tap-root, when laid out straight, was only 12·75 inches, and the end was not at this depth below ground. This particular example was dug up with the expectation that a particularly long tap-root would be found, and a good depth of soil. Quite the contrary, however, was the case. The soil was found to be very shallow, hard moorum being met

Fig. IV.



Length of root = 6·51 in.

1st Aug. 1908.

with 6 inches below the surface. From this point the root turned off at a sharp angle, seeking fissures which it could penetrate, and after numerous twistings and turnings came to an end at only 10 inches below the surface. The most remarkable point was the exceedingly hard nature of the moorum which the root penetrated, a strong pick being required to break it away. The tap-root had, in this instance, developed numerous side shoots, and was strongly developed.

This was no doubt an exceptional case, but none the less interesting.

(*iii*) *Dying off of the shoot.*—By about the middle of September the rains ceased altogether, and the grass, which, owing to the poorness of the soil, is never much more than from 6 to 10 inches in height, soon began to dry up, and by the 15th October the Anjan seedlings also commenced to show signs of withering.

On December 7th some further observations were made. On an area of about 8 yards square, 100 seedlings, taken haphazard, were examined to see how far the process of "dying off," which is so noticeable a feature of Anjan regeneration, had proceeded. The following results were obtained :—

Seedlings with shoot still alive, and with two upper leaves still green	10
Seedlings with shoot still alive, but all leaves dead . . .	52
Seedlings with shoot completely dead	38

Three seedlings of which the shoot in each case was completely dead were next dug up, the length of the tap-root measured, and the quality of the soil noted, as follows :—

Serial No.	Soil.	Length of tap-root.	REMARKS.
1	6 inches sandy loam, then hard moorum very little fissured.	12·5 inches.	
2	4 inches sandy loam, then hard moorum little fissured.	14·0 ,,	Root took a circuitous path, tip only 12 inches below surface.
3	4 inches sandy loam, then hard moorum very little fissured.	14·25 ,,	At 7·5 inches root divided into 2 branches, both same length.

These three examples differed in no special manner from those dug up in August and September. The tap-root appeared healthy, and was certainly still alive at this time. Unfortunately no comparison was made with seedlings of which the shoot was still living and green, but probably the only difference would have been that the roots of such seedlings had been able to penetrate somewhat deeper into the ground to moister layers. By February 15th not a single green seedling was to be seen, and of a very large proportion of them the shoot was also completely dead.

This brings us to the end of the first year's period of growth, and although the succeeding months, until the next burst of the monsoon, are very important ones in the seedling's struggle for existence, we can only wait and note the effect of that struggle after the monsoon has broken.

What has been described above may be seen going on on a larger scale in the forest, though the season of the drying up of the shoots may vary, and certainly does so, with the quality and depth of the soil, and quantity of moisture in the ground. In the case under observation the date—February 15th—is particularly early for all the seedlings to have lost their leaves, but the poor soil and early cessation of the rains is sufficient explanation. This state of affairs is generally reached by the middle of March, and by the beginning of June hardly a trace of the thousands of seedlings that were so conspicuous during the rains is to be seen.

(b) *Development during Second Year.*

(*i*) *The new shoot.*—We will now pass on, from the seedlings which we have watched germinate and make their first start in life, to the typical seedling in its second year. Let us start describing the second year's development by imagining a plot of ground—say one yard square—on which we counted 50 seedlings last year. We examine this plot just before the commencement of the second rains, and with difficulty we count 15 little brown stalks, which we take to be all that remains of our 50 seedlings. After the first month of rain we again count, and are surprised to find no less than 30 seedlings easily distinguishable by their one or two leaves. At first sight it appears as though new seedlings have sprung up, but on closer examination we find this is not the case. What has really happened is that the first shoot has entirely died down, while the root has survived, and, with the fresh lease of life in-

Fig. V.

2 Yr. old seedlings.

-

Fig. VI.

b *a* *2. Yr. old seedlings*

duced by the rains, has sent up a fresh shoot. The chief interest here is, where does this fresh shoot spring from ? For the answer to this question we must turn to Figs. V-VI.

Fig. V represents three actual two-year-old seedlings.

(*ii*) *Cotyledonary buds.*—A glance at the points marked *A* on the figure discloses on either side of the ascending stem a small bud. This point *A* marks the position where the cotyledons are attached in the seedling. These buds are best known as cotyledonary buds. In Fig. V it will be noticed that the buds are dormant, the main and original stem only having developed.

Now let us turn to Fig. VI (*a* and *b*). In Fig. VI (*a*) we notice that the main stem has died down, and one of the side cotyledonary buds has developed in its place. Fig. VI (*b*) shows a case in which the main stem has continued to develop, but in addition one of the side cotyledonary buds has begun developing and then died down again.

In Fig. VII (*a* and *b*) we find that both the cotyledonary buds have developed. The central stem has also died down, and has been replaced the following year by the development of one of the cotyledonary buds, which in its turn has died down, to be again replaced the third year by the remaining bud. It not infrequently happens that both side buds develop after the main stem has died down the first year, but only one of these becomes finally the leading shoot.

This peculiarity explains the phenomenon already alluded to, *viz.*, the small number of seedlings to be found on the ground just before the monsoon breaks, and the large increase in their number after a month of rain.

Not the least interesting part in the life history of the Anjan seedling is this "dying back" of the shoot. The process is common to several other Indian trees, for example the Sal (*Shorea robusta*) and the Teak (*Tectona grandis*). A complete comprehension of the causes of this phenomenon is, we believe, essential in deciding upon the sylvicultural system best adapted to the working and regeneration of our Anjan forests. Too much importance cannot be laid on this point. We have already remarked that poverty of soil and want of moisture are agents in this process of "dying back," but we shal reserve further consideration of this question to a later section dealing with the "Formation of Anjan Forests."

(*iii*) *Development of the shoot.*—The next point to claim our attention is the size and development of the second year's shoot. The most marked thing about it is its extremely small size, both as regards stem and leaves, when compared with the first year's shoot. It would appear that the plant was determined to concentrate all its energies towards the development of the root system. Figs. V and VI give some idea of the small size of the second year's shoot, as compared with Figs. II-IV.

(*iv*) *Development of the root.*—As regards the tap-root, development would appear to be more in the direction of circumference than in length. Fig. V may be compared with Figs. II-IV in this respect. The actual recorded length of two two-year-old seedlings was 20 inches and 27 inches, respectively. This, considering that seedlings in the first year attain a length of 20 inches, shows that comparatively little advance in the length of the tap-root is made during the second year.

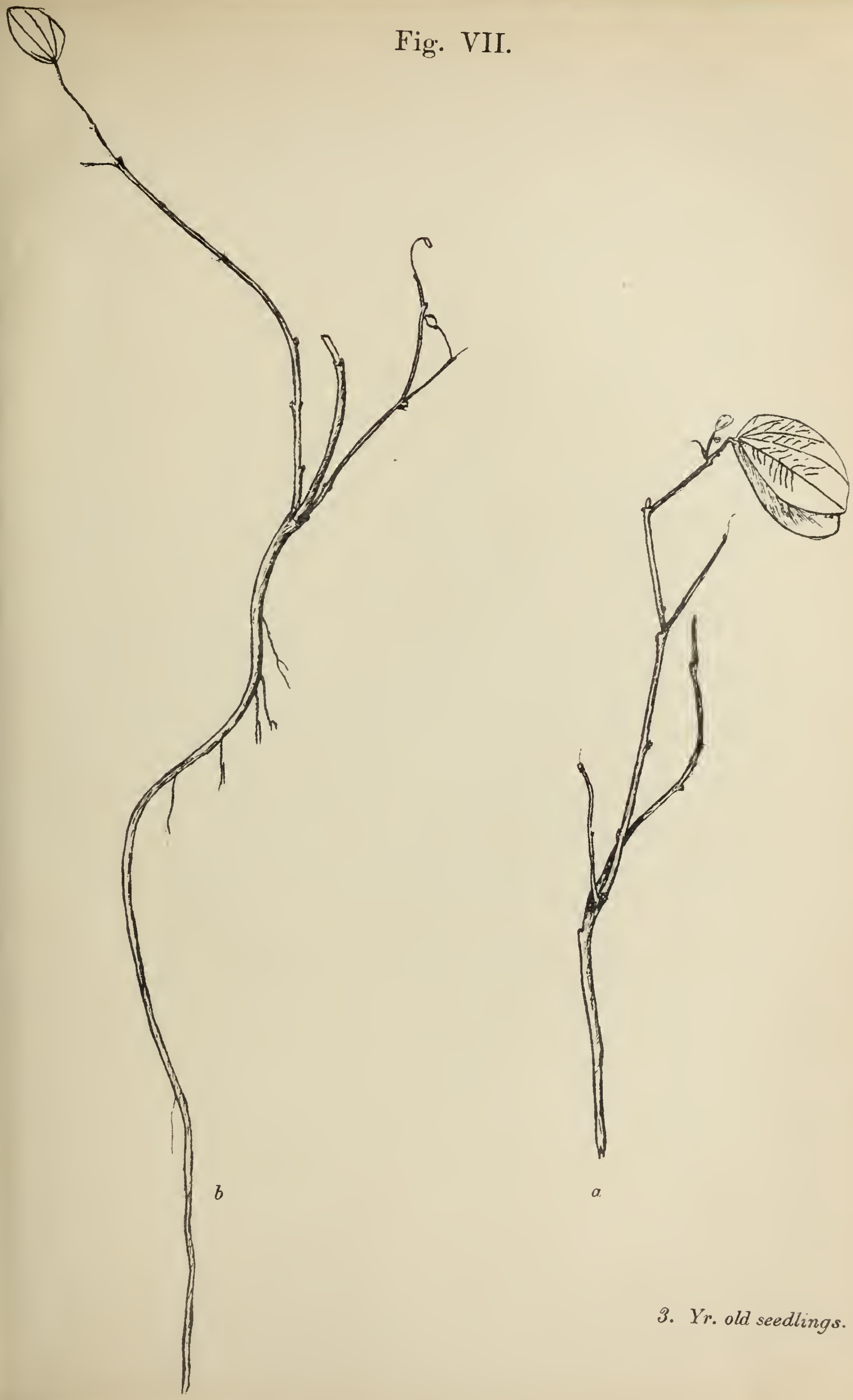
In judging of these lengths, and comparing them with the measurements recorded of the 8 seedlings dug up in Khandwa on August 1st, 1908, it is necessary to take into consideration the soil in which the seedlings were growing in each instance. In the case of the first year seedlings we found hard moorum at a depth varying from 8 to 16 inches. The two-year-old seedlings, however, were growing in soil consisting of 6 inches of deep loam, 6 inches of a mixture of loam and moorum, and 18 inches of loose disintegrating moorum, with harder portions in between. Thus there were 24 inches of easily penetrated soil for the tap-roots to grow down into.

A marked diminution in the number of lateral rootlets was also observed to have taken place, indicating that the seedling depends upon the lower layers of the soil for its moisture, which it then takes up through the tap-root.

(*c*) *Development during Third Year.*

(*i*) *Shoot development.*—Passing on to the third year we find exactly the same conditions as we found in the two-year-old seedlings. The shoot has again died back, and been replaced by a fresh one from the root column, and although the seedling is now three years old, this shoot is neither larger nor more vigorous than that of the second year. It is almost impossible to distinguish with any degree of accuracy

Fig. VII.



3. Yr. old seedlings.

Fig. VIII.

3 Yr. old seedlings.

6th Aug. 1908.

between a two and a three-year-old seedling by its size. Comparing Figs. IV and VIII (*a*), except for the cotyledon, who would imagine that Fig. IV represented a seedling one month old, and Fig. VIII (*a*) a seedling three years old?

(*ii*) *Root development.*—As regards the tap-root we again find that further development has been very slight and gradual. Fig. VIII depicts three three-year-old seedlings dug up on August 6th, 1908. They had therefore completed three years of growth, and were just entering on their fourth year. The figures are drawn to scale, life size. The different lengths of the tap-roots were 20·30 inches, 23·30 inches, and 30·3 inches, respectively. They were dug up within one foot of the spot from which the two-year-old seedlings were taken, and were therefore in similar soil, so that comparison is possible. From these examples it is clear that there has been very little development in length since the first year and still less between the second and third year.

On the other hand, there has been an appreciable thickening of the tap-root, as may be easily seen by comparing Figs. II, III, V, and VIII.

The tendency of the tap-root to lose its lateral rootlets, especially near the surface, continues, in fact it is at this stage the exception, rather than the rule, to find any lateral rootlets within 12 to 15 inches of the surface.

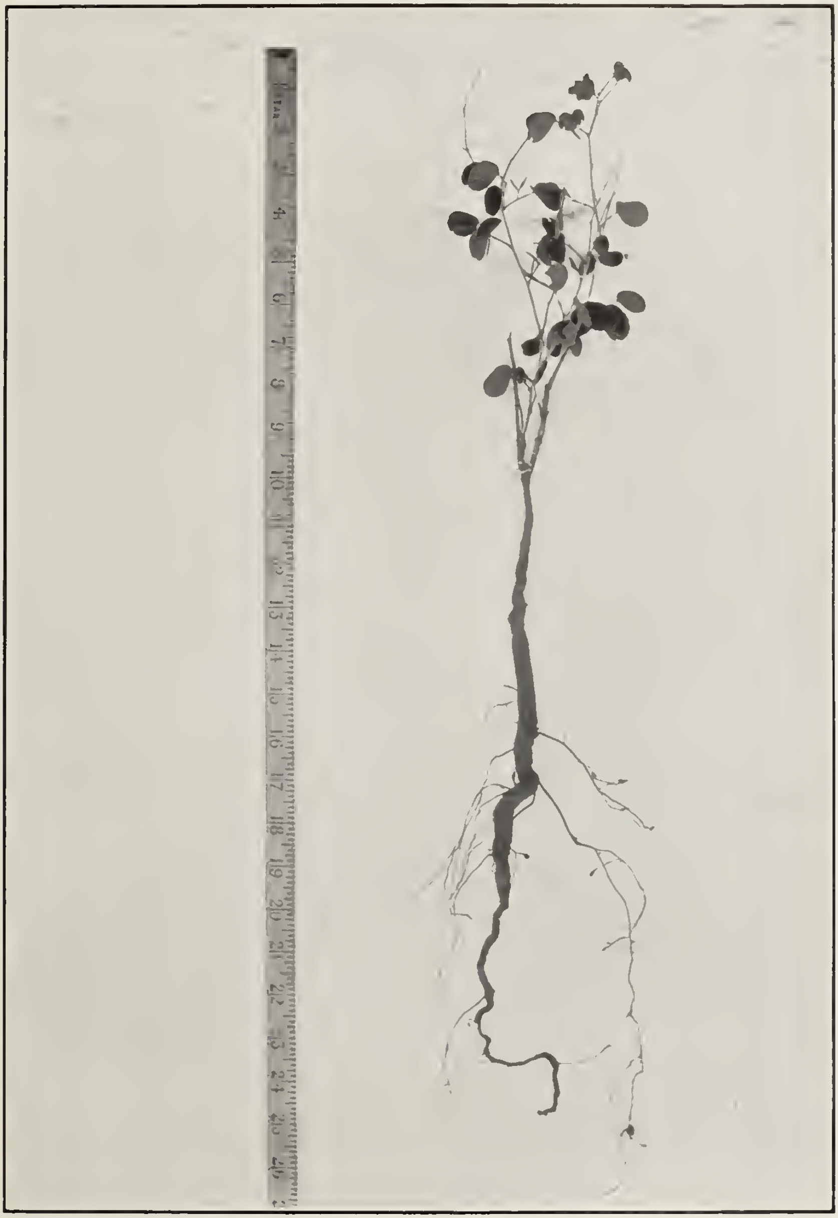
(*d*) *Development during Fourth and Subsequent Years.*

From the fourth year onwards we are much in the dark as regards the development of the seedling, until we find it a healthy sapling, shooting up rapidly 1 and 2 feet in a year.

All we know at present is, that those seedlings which get through the first two or three years of their existence, and they are few compared with the numbers that originally germinated, drag on an existence which appears to consist mainly of root development, the part above ground only very gradually developing into a little much branched bush 12 to 18 inches in height (see Plate A). Then suddenly a change seems to come, a leading shoot forms, and, provided it is not interfered with, starts growing in height a foot or more annually. The chief point to elucidate in this stage of the development is how long does it take the average Anjan plant to reach the stage where height growth commences. From general observations we believe the length of time to

be certainly not less than 10 years and probably considerably longer. Continuity of observation would soon set this point at rest.

The following statement, from actual measurements of typical Anjan seedlings, will give some idea of the nature of the development during this undetermined period :—



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YOUNG ANJAN ON TRAP ROCK ESTIMATED AGE 12 YEARS.

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Serial No.	Soil.	Height of plant above ground.	No. of shoots.	Circumference of stem at ground level.	Circumference of tap-root at base.	Length of tap-root.	REMARKS.
1	A shallow sandy loam, 3-6 inches in depth, followed by broken and disintegrating sandstone, passing into shale much fissured and easily broken, to a depth of 30 inches.	22 in.	1	1 in	1·92 in.	32 in.	Root column from 1 inch to 1·5 inches in length.
2		13 „	8	All under 5 „	1·93 „	42 „	
3		20 „	4	1·32 „	2·84 „	46 „	
4		11 „	1	·90 „	1·60 „	38 „	
5	A light sandy loam, followed by layers of shale very much fissured and easily disintegrating, to a depth of 3 feet 6 inches.	20·5 „	1	1 „	1·74 „	7 ft. 1 in.	Root very much twisted. Distance of tip of root from surface of the ground only 3 feet 6 inches.
6	15 inches of black cotton soil, followed by marl mixed with some of the black surface soil, to a depth of 2 feet, gradually passing over into a decomposing metamorphic sandstone at a depth of 3 feet 3 inches.	(1) 4 ft. (2) 2 „	2	2·5 „	4 „	7 ft. 7 in.	Root very much twisted. Distance of tip of root from surface of the ground only 4 feet.
7	6 inches of dry reddish sandy loam, then hard moorum very little disintegrated, down to a depth of 18 inches, passing over into solid trap rock.	13·5 in.	1	·8 „	1·2 „	14·6 in.	See Plate .

In one case only, serial No. 6, has height growth properly commenced. It will be noted that development is confined mainly to the root system and that the length of the tap-root depends to a great extent on the nature of the soil it is called on to penetrate. Serial No. 7 depicted in Plate A, though probably as old as Nos. 1-5, has an extremely short tap-root, due no doubt to the almost impenetrable nature of the soil.

(e) *Summary and Conclusions.*

It may be well to halt here a moment, and enumerate the chief facts we have learnt regarding the early stages of development of the seedling. They may be summarized as follows :—

(1) The seed requires to be subjected to a thorough soaking for some time before germination sets in.
(2) Growth is very rapid as soon as germination has set in, the principal development being in the formation of a tap-root.
(3) The length of the tap-root depends on the nature of the soil it has to traverse, deep loose soil favouring a long tap-root, and *vice versâ.*
(4) This tap-root may attain a length of 3 feet or more, that depending on the nature of the soil.
(5) The first year's growth is almost completed within the first two months of rainfall, subsequent development being very slight.
(6) The majority of the seedlings die down at the end of each cold weather, and produce fresh shoots the following rains by development of the cotyledonary buds.
(7) The second and third year shoots are not nearly so vigorous, as those of the first year.
(8) Root development after the first year is gradual but continuous and is in the direction of girth as well as length.

(3) THE SAPLING.

(a) *Its Appearance.*

We must now pass over the unknown interval of seven or more years and make a fresh start with a typical sapling which has just commenced its principal height growth. In the natural forests with

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TYPICAL ANJAN SAPLING COMMENCING ITS PRINCIPAL HEIGHT GROWTH.

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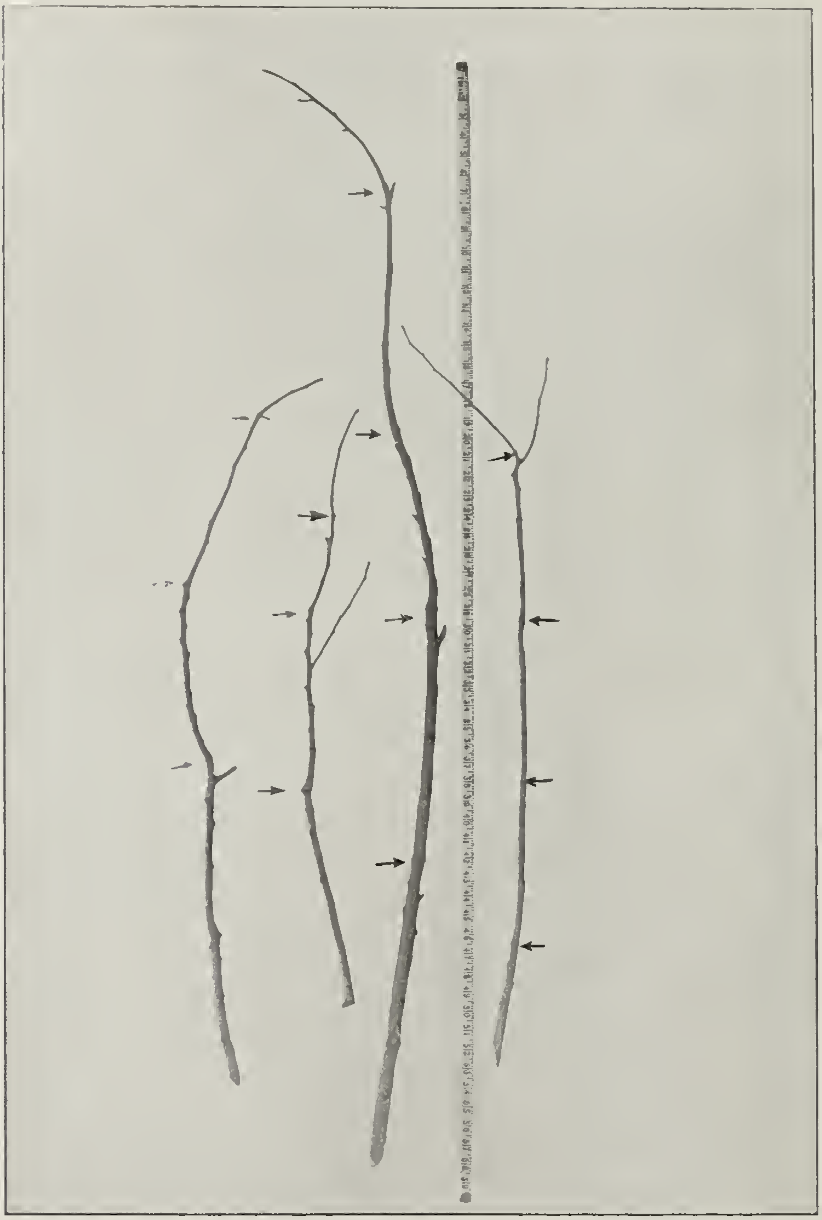

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ANJAN SHOOTS SHOWING ANNULAR RINGS.

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which we have to deal, and especially where grazing has been at all prevalent, our typical sapling has a very bushy and much branched base, from 1 to 2 feet in height, out of the centre of which rises a distinct leading shoot. Plate B shows this fairly clearly, except that in this instance, owing to damage by grazing, there are two leaning shoots striving for the mastery.

(*b*) *Shedding of Branches.*

To return to the leading shoot, a close examination of it will show, at intervals along its length, distinct annular marks or rings, usually in the form of a slightly raised ridge. Plate C shows some of these rings, the small black arrows indicating their position. These marks come in the following manner. Towards the end of the season of growth, about March, a portion of the year's growth is shed, much in the same way as leaves are shed. Just as a leaf scar arises from the shedding of a leaf, so does a scar result from the shedding of the woody shoots and branches. In April and May the ground under Anjan trees will be found to be littered with small twigs and branches, which, at first sight, appear to be have been broken off, but a closer inspection shows that they have literally been shed like leaves.

On the surface of the scar so formed a bud develops, which bud, the following year, grows out into the new year's shoot. There is thus a distinct ridge or scar left at the point where the branch has been shed, and these ridges can be traced back on the sapling for several years. From what has been said it is clear that each ring represents the end of a year's growth, and the space between two such rings represents, therefore, the height growth for that year.

These rings gradually become effaced as the sapling increases in girth, but from 4 to 6 years' growth can usually be fairly accurately deciphered.

(*c*) *Rate of Height Growth.*

From these rings we find that the average rate of height growth of a normal Anjan sapling, from a height of 3 feet onwards, is from 9 to 12 inches a year. How long this rate of height growth continues and whether it increases still further or afterwards decreases, are points still awaiting elucidation. As the sapling shoots up, the bushy appearance at the base disappears by a process of dying off, and, by the time the sapling is about ten feet high, it is usually clear of all

branches on the lower portion. The bark of the sapling is then smooth and an almost silvery white, and a patch of advance growth of young Anjan presents at that time a very conspicuous appearance. See Plate D.

(d) *Age of 10-foot Sapling.*

It may be interesting to calculate, from what has been said, the average age of a sapling 10 feet high. We start on the assumption that when height growth set in, the sapling was 3 feet high and 12 years old. A further growth of 7 feet, at an average rate of 10 inches a year, would occupy another 8 years, thus bringing up the age of the sapling at that height to 20 years.

As the sapling advances in growth to the pole stage, the only outward alteration in its appearance is the gradual change in the character of the bark, which becomes dark grey and rough, with irregular vertical cracks.

(4) Growth from the Pole Stage to Maturity.

(a) *Height Growth.*

We have been unable to obtain any statistics regarding the rate of height growth on the sandstone formations in the Nimar District, but as regards the growth on trap we have the following facts to go on. In 1874 some of the roads in the Civil Station of Khandwa were planted with Anjan trees. Assuming these to have been three-year-old seedlings, the present age of these trees would be 37 years. The average height of 45 of these trees was found to be 35 feet, which gives us an average growth of 9·3 inches per annum. The soil in this instance was extremely shallow, disintegrating trap being followed by hard trap rock, as a rule 6 inches below the surface. At the same time it is more than probable that pits with prepared earth were dug for the planting of these trees.

We have searched in vain for any statistics relating to height growth in other areas. The factors of the locality, and more especially the soil, have, of course, a decided effect on the height growth. Generally we may say that on sandstone formations under the best conditions Anjan frequently reaches a height of 80 feet and more ; Brandis says "occasionally 120 feet," but in the shallow soil of the trap formation it seldom attains a height of even 60 feet.

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ANJAN SAPLING GROWTH ON TRAP, KIRGAON RESERVE, NIMAR DIVISION, C. P.

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(*b*) *Volume Growth.*

(*i*) *General.*—We have found some difficulty in obtaining accurate statistics on this point, partly owing to the lack of information regarding the ages of planted trees, and partly to the difficulty entailed in the ring counting of felled trees, the rings in only a small proportion of the trees examined being clearly visible. The figures here given must therefore be taken with some reservation, but we believe they will be found to approximate fairly closely to the true rate of growth.

Data have been collected for growth on trap rock and on sandstone, as it was expected that a considerable difference would be found to exist in the rate of growth on the two formations. The fact that such is the case is borne out by the results obtained.

(*ii*) *Volume growth on trap rock.*—Taking the growth on the trap rock first, and referring to the 45 trees planted in the Civil Station of Khandwa, and already mentioned under height growth, girth measurements at breast height gave an average radius of 4·05 inches for the 45 trees, after deducting 1·0 inch for the thickness of the bark. The age of these trees we have already put at 37 years, so that the rate of growth works out as nearly as possible to 9 rings per inch of radius, which is not so slow as we should have expected.

(*iii*) *Volume growth on sandstone.*—Coming now to the growth on sandstone the following table shows the results of ring countings of 10 trees of various ages :—

Locality.	Serial No.	Average number of rings from centre to circumference of mean radius of 1″ (corresponding to true circles with circumference of 0′ 6″)	2″ (1′ 1″)	3″ (1′ 7″)	4″ (2′ 1″)	5″ (2′ 7″)	6″ (3′ 2″)	7″ (3′ 8″)	8″ (4′ 2″)	9″ (4′ 9″)	10″ (5′ 3″)	11″ (5′ 9″)	Average number of rings per inch of radius.	Remarks.
Coupes 7 and 8, Chickdaria Felling Series, Punasa Range, Nimar Division. *Soil.*—A sandy loam overlying hard crystalline sandstone.	1	13	22	35	43	53	66	79	90	104	116		11·7	126 rings counted, after that too close. Radius of heartwood 13·25 inches.
	2	16	28	42	56	71	86	99	116	136			15·3	150 rings counted to end of heartwood, with radius 9·80 inches.
	3	13	23	35	44								13·4	45 rings counted to end of heartwood, with radius 4·11 inches.
	4	13	31	54	81	106	134	159					22·1	169 rings counted to end of heartwood, with radius 7·69 inches.
	5	16	28	38	51	63	75	83	93				11·8	85 rings to end of heartwood, 97 rings to end of sapwood, with radius 8·50 inches.
	6	16	29	43	53	67	78						12·7	85 rings to end of heartwood, with radius 6·70 inches.
	7	17	28	43	54	71	83	90					12·8	96 rings to end of heartwood, with radius 7·80 inches.
	8	18	32	46	61	70	80	91					13·0	93 rings to end of heartwood, with radius 7·10 inches.
		..	29	46	61	79	90						14·9	92 rings to end of heartwood, with radius 6·20 inches.
	1	12	20	28	36	46	54						9·0	54 rings to end of heartwood, with radius 6·0 inches.
													10136·7	
													13·67	

Locality.	Average number of rings from centre to circumference of mean radius of 1·02″	2·27″	3·05″	4·21″	5·19″	6·13″	Average number of rings per inch of radius.
Kistna Canal, Madras Presidency .	5	15	20	30	40	50	8

It will be seen from these figures that the rate of growth varies very considerably in the different examples, from 9 rings per inch of radius to as many as 22 rings. These two examples may perhaps be taken as extreme limits, the average lying between 13 and 14. With these figures may be compared statistics of some trees of known age, planted on the Kistna Canal, Madras Presidency, taken from Gamble's "Manual of Indian Timbers," which we have included in the table. From them we learn the rate of growth to be on the average 8 rings per inch of radius. There is, however, no information with regard to the soil and underlying rock, which vitiates to some extent the comparison.

(*iv*) *Comparison of rate of growth on trap and sandstone.*—The data relating to the rate of growth on trap can be fairly well compared with that on sandstone, if we bear the following in mind :—The trees on the trap formation, having been planted in prepared soil and doubtless watered for the first few years, grew continuously, and were not exposed to the "dying back" process to which all naturally grown Anjan are subject, consequently the rate of growth in the earlier stages of the trees planted on the trap must necessarily have been very much more rapid than that of the naturally grown trees on the sandstone.

Bearing the above in mind, let us continue the comparison.

Our trees on the trap formation had an average radius of 4·05 inches at an age of 37 years, corresponding as nearly as possible to the trees of 54 years of age on the sandstone, taking this as the average age of the trees with a radius of 4 inches. If now we deduct 10 years, as being the time occupied by the naturally grown tree in establishing itself, we reduce the age of our 54-year-old tree to 44, and can then compare it directly with our trees planted on the trap formation, which have developed continuously. It follows from the above, that our 37-year-old planted tree on trap corresponds to a 44-year-old planted tree on sandstone ; that is to say, the rate of growth of planted Anjan on sandstone would average 11 rings per inch of radius as against 9 rings on trap, or in other words volume growth is more rapid on trap than on sandstone in the proportion of 11 to 9.

One other point in this connection deserves mention. The examples of ring countings were obtained from an area of which the underlying rock was that very hard crystalline Vindhyan sandstone already referred to under "*V.*—Locality : (*a*) Depth of Soil." This formation has a shallow surface soil, and other species do not thrive well on it. It is quite possible and even probable, that on the more porous and fissured

sandstone formations, where conglomerates and shales are intermixed, the rate of growth may be more rapid, and equal to that on the trap formation.

That volume growth, though comparatively slow on sandstone, continues for a very long period, is evidenced by the size of the old mature trees to be found in the Punasa Reserve. A girth of 8 feet is not uncommon, and trees up to 12 feet in girth are occasionally found.

(c) *Duration of Life.*

(*i*) *General.*—Judging from the size of some of the largest trees in the Punasa Reserve, the Anjan must be a very long-lived tree.

Taking the average rate of growth on sandstone to be 13 rings per inch of radius, a tree of 9 feet in girth, after allowing, say, 2 inches for the thickness of the bark, will represent an age of not less than 200 years.

(*ii*) *Unsoundness of old trees.*—Trees of this age appear quite healthy as regards their outward appearance, but a very large proportion prove to be unsound when felled.

Other observers have found this to be the case. Mr. E. M. Crowther, writing of the Anjan in the Kurnool District, Madras, says : " A peculiar feature is that very few trees of 6 feet girth are sound." Old Ranger, in some notes on Anjan in the Buldana Division, Berar, writes : " An enormous percentage of the stock in these Anjan forests is composed of old gnarled trees, *invariably unsound.*" The former ascribes this unsoundness to fires and dry hot seasons causing cup and heart shakes, and the latter to generations of lopping. We ourselves are more inclined to think that the " dying back " process, during the early stages of existence, creates a centre of infection, which becomes the seat of a fungoid disease, that asserts itself as the vitality of the tree diminishes through age.

Probably the Anjan tree reaches maturity and is at its best at an age of 100 years on the best soils, and at an age of 60 years on poor shallow soils

(5) COPPICE AND POLLARD GROWTH.

(a) *Coppice Growth.*

Opinions differ as to the coppicing power of Anjan. Mr. E. M. Crowther writes :—

> " Hardwickia stumps throw up a number of shoots from about an inch below the cut surface of the stump ; these shoots

continue to grow up in a bush till one takes the supremacy and the others then die down."

Mr. H. F. Arbuthnot, Deputy Conservator of Forests, writing of Anjan in the Bellary Division, Madras, says :—

"......in inspecting a coupe in the Sandur leased forests, which had been felled about two years ago, I found a stump which had been coppiced about 3 inches above the ground, but had not been very well trimmed. It had sent out two coppice shoots from well below the ground, both strong and straight, one a little more than an inch in diameter and about 5 feet high, and the other rather smaller. This will probably be considered very slow growth for coppice, but it should be remembered that the growth of all species is very slow in this dry district."

On the other hand "Old Ranger" writes :—

"In Berar Anjan does not coppice successfully; the stools frequently produce numerous coppice shoots, but these never advance beyond a slender drooping stage and gradually all die back."

Mr. E. E. Fernandez, retired Conservator of Forests, who had much experience of Anjan in Nimar as Divisional Officer, and later as Conservator in Berar, makes the statement :—"The tree will moreover not coppice." (*Vide* the *Indian Forester*, Volume XXIX, page 524.)

We ourselves are not of this latter opinion. We have seen coppice shoots 9 years old with a height of 14 feet, from an Anjan stool 2½ feet in girth. The growth was on trap rock with not much depth of soil. The differences, in our opinion, can be explained. In Berar the majority of trees felled are old lopped and pollarded trees, mostly unsound, and all of great age. According to our own observations the stools of such trees do not produce coppice shoots, and very naturally, in our opinion. This has led to the rather sweeping statement that "the tree will moreover not coppice." We hold, however, that this statement is only applicable to the old lopped and pollarded trees referred to above, and that further experience will show that a good healthy seedling Anjan tree up to a girth of about 3 feet will not only coppice, but will coppice very well whether on trap or sandstone.

(b) *Pollard Growth.*

On the other hand, there is but one opinion as to its pollarding capabilities, which is that it pollards extremely well, and to a comparatively late age, differing in this respect from its coppicing power, which disappears before maturity is reached. To its capability of pollarding, and to the value of the leaves as fodder, may be attributed the large number of old pollarded trees that are still found all over the Anjan areas in Berar, Nimar, and elsewhere. (See Plate E.)

On account of the very hard nature of the timber it is the custom in Nimar to fell large Anjan trees over 4 feet in girth at a height of from 3 to 4 feet from the ground. Such stumps, though anything from 100 to 200 years old, almost invariably send up strong pollard shoots which develop into fair sized poles. Trees of this age, however, if cut flush with the ground, will never produce coppice shoots.

NOTE.—Since writing the above section some fresh notes on this subject by Mr. L. S. Osmaston, have appeared in the June and July, 1909 number of the *Indian Forester*.

His figures relating to the coppicing power of Anjan are peculiarly instructive and are the first serious record of this nature we have come across. We do not propose to quote from the article, but it deserves careful perusal and consideration. Sufficient to say here, that the results of the observations made tend to show that, irrespective of the height and circumference of the coppiced stump, barely 50 per cent. of such stumps produce coppice shoots.

Engraved and printed by. Survey of India Offices Calcutta, 1910.

OLD POLLARD ANJAN ON SANDSTONE, PUNASA RESERVE, NIMAR DIVISION, C. P.

[TO FACE PAGE 108.

PART II.

Formation and Tending of Anjan Forests.

PART II.—FORMATION AND TENDING OF ANJAN FORESTS.

I.—Character and Composition of Anjan Forests.

(1) TYPES OF ANJAN FORESTS.

(a) *Pure Forest.*

The gregarious nature of the Anjan lends itself to the formation of pure crops, but the most important factor in producing these pure forests appears to be the nature of the soil, and underlying rock. Under the heading "Distribution and Composition of Anjan Forests in Nimar", we have already shown that the pure forests are entirely confined to the trap formation with its shallow, overlying soil. The most noticeable feature in this type of forest is the absence of natural reproduction. That the tree can reproduce itself naturally on this soil goes without saying, for otherwise this type of forest could never have arisen. It will be our endeavour, further on, to give an explanation for this phenomenon. Trap rock alone does not bear pure Anjan forest. In a letter from E. D. M. Hooper, Esq., Conservator of Forests, Central Circle, Madras Presidency, to the Conservator of Forests, Berar Circle, Central Provinces (*vide Indian Forester*, Volume XXXI, page 102), we read : "In the Ahiri Zamindari to the south of the Bhimaram reserve, Anjan was found in 1881 over a restricted area—a pure forest, the stems being strangely uniform, varying in girth from 5 to 6 feet, and in height from 40 to 60 feet, with clear straight bole. The soil was a quartzose red gravel, crunching under foot, and I have generally observed that wherever Hardwickia is very prevalent this soil occurs."

Generally we may say that pure Anjan is confined to the shallowest and poorest soils, the reason being, most likely, that other species are not able to compete with it, on such soils.

For the rest, reference may be made to what has already been said under "Distribution and Composition of Anjan Forests in Nimar."

(*b*) *Mixed Forest.*

This type is exemplified in the forests of the Punasa and Chandgarh Ranges of the Nimar Division, already described.

We need not here add to the description given, except to note that this type is, as a rule, denser than the pure forest, that the middle age classes are very poorly represented, the majority of the Anjan stock consisting of old mature trees, and that natural regeneration is not infrequently to be found in the form of small patches of advance growth.

(2) ABSENCE OF NATURAL REGENERATION.

(*a*) *General.*

The general complaint of most Foresters, who have had to do with *Hardwickia binata*, is that there is no reproduction to be found in the existing Anjan forests. This applies to both the pure and the mixed type.

To quote but one instance of this lack of reproduction, Mr. E. E. Fernandez, when Conservator of Forests, Berar, wrote with reference to the Anjan forests of the Buldana Division :—

> "*Anjan forests*.—This is here a most unsatisfactory type. The species is incapable of attaining the dimensions of sawyer's timber, and can at the most furnish small house-posts. But the worst about it here is that there has been absolutely no reproduction for at least 20 years (I should have more correctly said 30 years), although there has been abundant seeding every 3-5 years. After each seeding numbers of seedlings come up, but all disappear before the end of the ensuing hot weather."

The matter is one of paramount importance, as upon the satisfactory reproduction of the species must depend the continuation of the existing forests. One thing is quite certain. The existing forests arose naturally, and not by planting, or any other artificial process. Consequently where such forests have arisen, and now exist, there must, at some time or other, have existed conditions suitable to their formation. Having once existed, it must surely be possible to recreate similar conditions for the further reproduction of these very forests. During the last four years, while in charge of the Nimar Forest Division, we have constantly kept this view before us, and we hope to show, by observations made and

experiments carried out, that the explanation for the present dearth of natural reproduction is not far to seek, and of more importance still, that the conditions necessary for the successful reproduction of the species are by no means difficult of attainment.

(*b*) *Existing Theories to account for Absence of Natural Regeneration.*

Various notes, on the sylviculture and treatment of Anjan, have been written at different times in the *Indian Forester*, from several of which we have already had occasion to quote.

None perhaps have gone so much into detail on the subject as Mr. E. E. Fernandez, retired Conservator of Forests. As Forest Divisional Officer in Nimar, and later as Conservator of Forests, Berar Circle, he had unique opportunities of studying this species from all aspects, and he specially went into the important question of the lack of natural reproduction and its causes. His opinions and observations therefore deserve full consideration. It is easy to pull a theory to pieces. It is more difficult to substitute another in its place.

At the same time we are quite unable to agree with Mr. Fernandez's very decided views. If in criticizing we thereby destroy these views, it will be in the endeavour to substitute an alternative and, it is hoped, more satisfactory theory.

In order to fully understand Mr. Fernandez's views, it is necessary to peruse carefully his article entitled "The Treatment of Hardwickia binata" in the *Indian Forester*, Volume XXIX, pages 517-527. It is unnecessary to quote the whole article here. We shall content ourselves with extracts to give the general idea. On page 525 of the above-mentioned article Mr. Fernandez writes :—

> "As already explained above, we have still to devise a means of saving a sufficient proportion of the myriads of seedlings that make their appearance at each periodic fructification of the species. *There is no doubt whatsoever that the death of the seedlings is due to their inability to force their long slender tap-root down deep enough through the matting of grass roots, occupying the soil everywhere to a depth of 1-2 feet.*"

* * * * * * *

Again :—

> " In the Punasa forests in 1874, when I took over charge of them, I found the most perfect new reproduction wherever there had recently been field cultivation. . . . . .
> In October the seedlings began rapidly to wither, and by the middle of the hot weather there was scarcely a single one alive ; *the inability of the tap-roots to penetrate through the dense mass of grass roots was the cause of their death.* . .
>
> " During the 7 years that I was able to continue my observations, before I was transferred to the United Provinces, the seedlings of pre-reservation days continued to strengthen themselves and develop, but no new contingent of seedlings survived to swell their numbers, and in my inexperience, and under the influence of the erroneous idea, unfortunately still very generally prevalent, that the exclusion of fires and cattle was the one panacea for all our forest ills, I attributed the death of the new seedlings exclusively to the annual conflagrations . . . . .
> *We are now wiser, for we have learnt that more than 20 years of successful fire prevention have given us no better results. The seedlings are as usual produced in countless numbers after every periodie gregarious seeding, but, being unable to push their tap-roots down deep enough, they all perish in their first year.*"

The above remarks refer especially to the type of Anjan forest growing on sandstone. They apply, however, equally to the Anjan growing on trap as may be seen from the following :—

> " On trap the Anjan is a very small tree, and has quite a different habit of growth. Moreover, besides the periodic gregarious seedings, a few trees here and there, scattered or in small groups, are to be met with every year in fruit during the interval. Nevertheless, *reproduction is no more successful here than in the sub-type growing on sandstone.* Indeed, the chances of survival, on the class of trap affected by the Anjan, are less favourable than on sandstone, which always offers numerous deep fissures for the downward development of the tap-root of the seedlings."

* * * * * * *

"*I feel certain that my diagnosis of the reason of the failure of Anjan to reproduce itself from seed is absolutely correct,* and that the only remedy for it is to devise some practical, and therefore necessarily cheap, method of keeping down the grass at numerous points not too far apart from one another, in anticipation of a gregarious seeding."

The above extracts formulate briefly Mr. Fernandez's theory to explain the absence of natural reproduction in our Anjan forests. Before entering into a discussion on his views, it will not be out of place to quote the opinions of some other Forest Officers, who have studied this subject.

A very decided partisan of Mr. Fernandez is Mr. L. K. Martin, Extra Assistant Conservator. An extract from his Annual Report for 1903-04 quoted by Mr. Fernandez in the Berar Administration Report for 1903-04 (*vide Indian Forester,* Volume XXXI, page 105) reads as follows :—

"The Anjan seeded very fairly profusely in the spring of 1902, and the seed germinated freely during the following monsoon, along the Ajanta Hills, especially in the Geru-Matargaon Range around Botha and Matargaon. *A very noticeable feature was the complete absence of seedlings from the midst of dense grass, that is, from areas entirely closed to grazing. They appeared wherever the grass was light, and increased in numbers with decrease in density of the grass, till over areas free of grass the seedlings were quite dense.*"

* * * * * *

"*In the portions of the reserve closed to grazing, and consequently covered with a dense crop of grass, Anjan seedlings were completely absent,* except just along roadsides; whereas in Survey Nos. 1, 2, 3, and 6 of Chinchker, which were open to heavy grazing, and being situated close to a public road, were much resorted to by cattle, and as a result absolutely clean grazed, thousands of seedlings have sprung up, and stand out uninjured and perfectly healthy. The above appears to prove conclusively that a dense growth of grass is inimical to the successful reproduction of Anjan. The seedlings observed in those Survey numbers having survived the past two hot weathers, and escaped injury from cattle during the same period, when, in the absence of other

fodder, cattle might have been expected to browse them off, grazing throughout the year must obviously be looked upon as a distinct advantage, in fact a real necessity."

On the other hand, we find that the observations and conclusions of Mr. H. F. Arbuthnot, Deputy Conservator of Forests, are entirely at variance with those of Mr. Fernandez and Mr. Martin. On page 123, Volume XXX, *Indian Forester*, Mr. Arbuthnot writes as follows regarding the Malapanagudi block in the Bellary District :—

"This block is an interesting one, as it has been under special protection from grazing, cutting, and fires for the last 25 years. The result has been that most of the area, which was then presumably blank, has been stocked with Yepi (*Hardwickia binata*) which is the principal species of the block. This species now appears on the ground in different aged groups, from old trees down to young seedlings. There are groups representing all ages. From examination of the younger plants it seems to me that it takes at least six or seven years before a seedling really becomes established, and begins to grow ; till then it dies off every hot weather. Very possibly the necessary time for a seedling to become established is even longer. There are still a few blank areas which remain unstocked, but seedlings are scattered sparsely over these two."

We would specially draw attention to the views of Mr. J. B. Fry, Conservator of Forests, Bombay Presidency, in a letter to the Conservator of Forests, Berar (*vide* the *Indian Forester*, Volume XXIX, page 527) :—

"The tree seeds more or less irregularly every year, and abundantly every third or fourth year, but in spite of this one never finds a dense growth of saplings. Throughout Khandesh and Nasik, where the tree is fairly abundant in parts, I have almost invariably noticed that the trees are dotted about singly, 20, 30 or more feet apart. *In our case fire and grazing may have had something to do with this, especially in Khandesh. If we could protect seedlings from these two dangers, I believe that many more of them would survive*, though possibly the open nature of the forests in which the Anjan grows may have something to do with the

great mortality among the seedlings. *Perhaps they cannot stand the fierce hot weather to which they are exposed, and something might be gained by introducing nurses.*"

The italics in the above extracts are our own, and are for the purpose of drawing attention to the main points of view of the different observers.

Briefly put it comes to this. Mr. Fernandez holds that a dense growth of grass is absolutely fatal to the natural regeneration of Anjan, and consequently that fire protection and closure to grazing are distinctly inimical to its development.

The opponents of this view, on the other hand, including ourselves, hold that protection from fire and grazing are beneficial, and suggest other causes to explain the heavy mortality of Anjan seedlings.

We will now describe certain experiments carried out and observations made, which have led us, after full consideration, to discard Mr. Fernandez's theory.

(*c*) *Investigations to ascertain the Cause of Death of Anjan Seedlings.*

(*i*) *General.*—In studying the question we were materially aided by three facts : (1) that we already had a definite theory before us as a basis for investigation ; (2) that this theory was formulated with reference to the identical forests in which we carried out our own observations ; (3) that we were fortunate enough to be able to extend our observations over an uninterrupted period of four years.

(*ii*) *Comparison of germination on grass-covered areas with those devoid of grass.*—To begin then, in May 1905 there was a profuse seeding of Anjan in the Khandwa, Punasa, and Chandgarh Ranges of the Nimar Division.

The Anjan in the Khandwa Range is, as already described under " IV.—Distribution, " entirely on the trap formation. For convenience, an area in the Kirgaon block in this range was chosen for the purpose of experiment and detailed observation. Some coupes, which had recently been worked over and were consequently closed to grazing, afforded a suitable field for detailed observation, while general observations were made over all the area affected by the seeding.

The seed which fell in May 1905 came up profusely, in all areas both closed and open to grazing, during the following monsoon months. Between the 11th and 15th January 1906 we inspected these areas. The grazing in the open areas is so heavy here that as fast as the grass comes up it is grazed off, consequently, as we expected, there was practically

nothing to be seen of the Anjan seeding on such areas. On the other hand, the areas closed to grazing were full of seedlings. In places the ground was literally carpeted with them, large patches not infrequently containing from 50 to 80 seedlings to the square yard.

It was particularly noticeable that the seedlings had come up equally well on poor and on good soil, and in long grass as well as on areas covered with a very poor short growth of grass.

This latter observation, it will be noted, is contrary to that made by Mr. Martin in the Geru-Matargaon Range, in Berar, and we are quite unable to offer an explanation for this divergence in observed facts, not having seen the area ourselves. We are, however, inclined to believe that some other factor was at work, a very likely one being the comparative absence of seed-bearing parent trees in the areas closed to grazing and covered with a dense crop of grass.

(*iii*) *Experiment to test effect of grass roots on seedlings.*—Having noted that the initial germination of the Anjan was as satisfactory on areas clothed with a dense growth of grass as on those devoid of grass, the question that arose was, could the growth of grass affect the Anjan seedlings later on, that is, would the seedlings in long grass gradually die off, while those on ground not so clothed survived ?

On the occasion of this inspection the seedlings were but six months old ; consequently there was a possibility that the full effects of the dense growth of grass had not yet made itself felt.

To test this, two experimental plots, each 1 yard square, were chosen and pegged out, the one in an area covered with a good growth of grass, and the other where the grass was of the thinnest and scantiest description. The quality of the soil was noted in each case, and the number of seedlings on each plot was carefully counted.

If now Mr. Fernandez's theory was correct, other factors being equal, the seedlings on the area clothed with grass might be expected to die off, while those free of grass survived. What actually happened was, however, just the reverse.

For the sake of comparison we will now give a description of each plot, and tabulate the results of the observations made.

PLOT I.—*Situation.*—In the middle of a blank of about half an acre on flat open ground. The whole of this blank was carpeted with Anjan seedlings in January 1906.

Surface covering.—A thin growth of "bhurri" grass about 6 inches high, the roots penetrating into the soil to a distance of 2 to 3 inches.

Soil.—6 inches of dry reddish sandy loam, then hard moorum, very little disintegrated and with few fissures, requiring a pick to break it, down to a depth of 18 inches from the surface, passing over into solid trap rock.

PLOT II.—*Situation.*—On the flat top of a small ridge within a quarter of a mile of Plot I. Surrounded by tree growth, the plot itself under the shade of a Salai (*Boswellia serrata*) tree.

Surface covering.—A dense growth of long grass, 30 inches in height, with roots penetrating into the soil to a depth of 6 inches.

Soil.—Six inches of good loam, followed by 6 inches of a mixture of loam and moorum. Then 18 inches of loose, disintegrating moorum with harder portions between, gradually passing over into hard moorum and trap rock.

Experiment I.

Date of counting of number of living seedlings.	No. of seedlings alive.		Age of seedlings.		Remarks.
	Plot I.	Plot II.	Y.	M.	
10th March 1906 .	41	61	0	8	
16th July 1906 .	0	40	1	0	
3rd December 1906 .	1	45	1	5	
29th September 1907	0	43	2	3	
22nd March 1908 .	..	37	2	9	
6th August 1908 .	..	35	3	1	
7th January 1909 .	..	36	3	6	

The first thing to strike us in comparing these results is the complete dying out of the seedlings on Plot I in the first year, and, secondly, that they all died between the months of March and July, that is, *during the hot dry season.*

On the other hand, in Plot II, taking the number 45 counted on 3rd December 1906, we find that no less than 74 per cent. of the seedlings survived.

The excess of 1 and 5 in the countings of 3rd December 1906 over those of 16th July 1906 need not trouble us. It is easily explained by the fact that the counting on 16th July 1906 was made at the commencement of the rains. The 5 seedlings which appear later in excess were, no doubt, still lying dormant after the dying back process of the hot season, to which we have already alluded when describing the growth of the seedling.

To return to our consideration of Plot I. It is impossible that the growth of grass accounted for the death of the seedlings, since there was practically no grass on the plot. Again, we have already shown under "VI.—B(2) The Seedling" that the development of the tap-root is exceedingly rapid to begin with, and that the first season of growth is practically completed within three months of germination ; consequently, had the seedlings not been able to force their tap-roots through the few inches of grass roots near the surface, it is not likely that they would have lived even up to 10th March 1906, when the first counting was made.

We would also draw special attention here to the full description of the development of the seedlings in our compound at Khandwa. Here the soil is exactly similar to that of Plot I, and yet we have demonstrated that the tap-root can and does bore its way down in a marvellous manner through what appears to be almost solid rock. With such facts before us, it seems impossible to believe that even a thick matting of grass roots, let alone the very thin layer in this case, could in any way hinder the development of the tap-root. This drives us to seek some other explanation for the death of the seedlings on Plot I.

It may still be argued that, although the death of the seedlings on Plot I cannot be attributed to an impenetrable layer of grass roots, it does not follow that such a layer is not prejudicial to the development of Anjan seedlings. For the answer to this objection, we must consider in detail the development on Plot II, and some general observations made throughout the area.

Reverting then to the countings on Plot II, chosen for its thick growth of grass, we find that after one year and five months of growth 74 per cent. of the seedlings are still alive.

Their tap-roots have evidently not been prevented by the grass roots from developing. At the age of 2 years 3 months, after a second dry season, 70 per cent. are still surviving, and after a third dry season, the seedlings being now 3½ years old, we still find 59 per cent. alive.

That the mortality, during the second and third season of growth, is not due to the grass roots is quite certain, for the tap-root is well below the level of these roots by this time. The actual lengths of the tap-roots of the surviving seedlings may be gauged by comparison with the examples of 2 and 3-year-old seedlings given on pages 96 and 97.

These were dug up within a few inches of Plot II and are therefore typical of the seedlings on this plot.

(*iv*) *General observations made on the effect of a growth of grass on seedlings.*—The general observations made at each inspection gave similar results.

The value of these observations will be increased by quoting a few of them as recorded at the time.

"Inspection of Anjan seeding in Khandwa Range on 3rd December 1906."

"Examined the same areas as in January 1906."

"Dug up a seedling on shallow poor soil where 'bhurri' grass only was growing. The grass roots only penetrated a few inches. The seedling had a tap-root of which I dug up 14 inches when it broke off; it was probably at least 6 inches longer. Yet on this class of soil the majority of seedlings have perished."

"On a south slope covered with boulders and very long grass (kajeli and seri), on removing the covering of grass, I counted, in a space 5 yards by 3 yards, no less than 43 green healthy seedlings."

"A northern slope covered with boulders and long grass was a regular carpet of seedlings, so was the south slope alluded to above, and also a north-west slope."

"It was very noticeable that the seedlings which are protected by a long growth of dense grass over them are all *quite green*, while those not so protected have, already in many instances, begun to lose their leaves.

"The greatest number of seedlings are on ground covered with a dense growth of grass."

"Inspection on 7th January 1909."

"Growth of grass in coupes 29 and 6 fairly thick."

"Seedlings under cover of grass all green. Grass has been cut a good deal for extraction. Where seedlings are thus exposed they are already beginning to wither."

The above observations, so far from proving grass to be inimical to the seedling by preventing development of tap-root, tend to show that a growth of grass may be distinctly beneficial and helpful in acting as a protection or nurse to the delicate seedlings.

(*v*) *Experiment to ascertain whether the development of seedlings is impeded by a growth of grass.*—Having satisfied ourselves by these experiments and observations that the roots of the grass did not interfere with the development of the seedlings, the question arose whether the dense growth above ground might not perhaps choke and smother the seedling, and so prevent its development.

To test this another experiment was devised. Two plots, each measuring 2 yards by 1 yard, were laid out adjoining each other on a north-west slope covered with a dense growth of grass $2\frac{1}{2}$ feet in height.

The soil was very similar to that of Plot II, but interspersed with numerous boulders of trap. The grass roots penetrated to an average depth of 6 inches.

From one of these plots the grass was kept down by cutting, whilst from the other plot the grass was not removed. Countings, at stated intervals, were made of the seedlings in each plot, with the following results :—

Experiment II.

Date of countings of number of living seedlings.	No. of seedlings alive.		Age of seedlings.		Remarks.
	Plot III. Grass removed.	Plot IV. Grass not removed.	Y.	M.	
21st December 1906 .	171	..	1	5	Plot IV was not laid out until the following year.
20th July 1907 .	180	180	2	1	
22nd March 1908 .	209	177	2	9	By mistake the grass on Plot IV was cut in January so that the plot was exposed throughout the dry season of 1908.
6th August 1908 .	159	81	3	1	
7th January 1909 .	171	83	3	6	

It must be stated at once that this experiment has not been altogether satisfactory, and is not entirely convincing. The figures show several discrepancies, which lead one to suppose that the countings were not always very accurate, though every care was taken to make them so.

The experiment was further interfered with by the removal of the grass on Plot IV in January 1908. In spite of these drawbacks, it is possible we think to draw certain inferences from the above figures, which we will now consider in detail.

In Plot III we must first notice that when these seedlings came under observation they had already successfully survived one hot weather, in spite of the long grass over them. After the second hot weather we find the number has increased to 180, and by the following March to 209. While admitting this to be an objection, the increase can be explained by one of two causes. Either the first counting on 21st December 1906 was inaccurate, or two shoots of one seedling have been counted as two separate seedling in the second and third countings, an error which might very easily occur. The subsequent countings do not show very much variation. Taking the figures as a whole we may say the cutting of the grass has not affected the seedlings one way or the other.

The figures of Plot IV on the other hand give a very different result. Supposing the dense growth of grass to be the main cause of mortality in the seedlings, we should have expected a very large drop in the number between the countings in July 1907 and March 1908, but such is not the case. On the other hand, we do get a very large difference after the second dry season has been gone through, *viz.*, between the countings in March 1908 and August 1908.

But through an accident the grass was cut from this plot early in January 1908, so that the plot was fully exposed throughout the dry season of that year. Obviously the death of such a large proportion of the seedlings, more than 50 per cent., could not be due to a growth of grass. On the contrary it would appear that the removal of the grass was to a great extent the cause, in that the seedlings were thereby suddenly exposed to the full effect of the sun and scorching hot winds of the dry season. If we note also that the rainfall of 1907-08 was extremely short, only 17 inches, we can more fully appreciate what effec this exposure would have on the seedlings, already fighting for existence against an exceptionally dry season.

It will probably be asked, why did the seedlings in Plot III not show the same mortality, since here also the grass was cut ? to which the

answer would appear to be that, as the grass had been removed from this plot already since December 1906, the seedlings on it were more acclimatised to exposure to excessive heat and evaporation.

The results of this experiment must be taken for what they are worth, but it will add to their importance to append some general observations made when carrying out the countings.

Date.	Plot III.	Plot IV.
6th August 1908 .	83 out of 159 seedlings have produced new shoots from the root column. The longest shoots measure 7¼″, 6¼″, 5⅜″, 5½″. The majority are between 2″ and 4″.	17 out of 81 seedlings have produced new shoots from the root column. No noticeable difference from the seedlings kept clear of grass.
7th January 1909	Without exception all the leaves have dropped and the shoots are beginning to dry up.	Without exception all the seedlings have their leaves, which so far show no signs of withering. All the plants look healthy. Grass dense, average height 2 feet.

Of particular interest are the notes made on 7th January 1909, showing clearly that the grass acts as a protective covering to the seedlings against the sun's rays, hinders evaporation, and lengthens the seedlings' period of vegetative activity.

(*vi*) *Results of investigations.*—This completes our case against Mr. Fernandez's theory. It will be well to briefly sum up the results of our investigations, before attempting to put forward an alternative theory.

They may be summarized as follows :—

(1) Grass, as such, does not hinder the germination of Anjan seedlings.

(2) Anjan seedlings may fail to survive on soil quite free of grass.

(3) The tap-root of the Anjan is quite capable of penetrating through any obstruction of grass roots.

(4) The first season of growth is the crucial one in the life history of the seedling, the mortality being then the heaviest.

(5) Seedlings on soil clothed with grass retain their leaves for a longer period than those on soil not so clothed.

(6) The shoots of seedlings protected by a long growth of grass do not dry up so early as those from around which (though on precisely similar soil) the protecting grass covering has been cut away.

(7) Seedlings up to an age of 3½ years are not smothered and killed by a dense growth of grass weighing down upon them.

(8) The removal of a covering of grass, from seedlings which have developed under its protection, may be distinctly harmful.

(d) *Explanation for Absence of Natural Regeneration.*

With the above facts before us, we will endeavour to explain what we believe to be the true reasons for the dearth of natural regeneration in many of our existing Anjan forests.

(i) *Insufficiency of moisture in the sub-soil.*—As already stated, the Anjan when it seeds reproduces itself prolifically. We may look on this as a dispensation of nature to aid the Anjan in its task of reproduction. Nature never intended that every seed should develop into a mature tree. The growing space would never suffice to permit every seedling to reach maturity. The myriads of seeds are strewn by the wind in all directions, and fall alike on good, bad, and indifferent soil.

As soon as germination sets in, the tap-root starts on a race, which has, we believe, for its object the reaching of a permanent water level before the dry hot season commences. Failing in this object, the seedling perishes, being unable to replenish through its tap-root the moisture lost by evaporation.

Naturally the seed which has fallen on rock and very poor shallow soil is the first to succumb, for not only will the permanent water level be low down, but the resistance afforded by the rocky nature of the soil to the penetration of the tap-root will be very great. This will partially explain the death of all seedlings on Plot I and on similar soil. But even on such soil a few seedlings may be found to survive. Here the prodigality of nature comes to the rescue. Out of the myriads of seeds that germinate, one or two find themselves in a favourable position, where an existing fault, or crack, or other weakness in the underlying rock, enables the tap-root to develop and reach a permanent water-supply, where otherwise it could not possibly do so.

Some of the seed, however, is more fortunate, and falls on richer and deeper soil, where it is in a very short time able to drive its tap-root down

to a permanent water supply. There are, as we know, great variations in the depth and composition of the soil, even in restricted areas. According as the seed has fallen on each class of soil will its ultimate survival depend.

It is the soil, its depth, composition, the resistance it offers to the development of the tap-root, and, above all, the supply of moisture in the sub-soil level, which is primarily responsible for the survival or death of the seedling, and not grass roots which, we have shown, are easily penetrated by the powerful tap-root.

(*ii*) *Insufficient protection against excessive evaporation.*—Now since a certain amount of moisture, especially during the dry months of the year, is absolutely essential to the life of the seedling, it follows from the above that the seedling which can reduce its requirements to the lowest minimum will have the greatest chance of survival.

The less a plant transpires through its leaves, the less moisture does it require to take up through its roots. The more, then, evaporation and transpiration can be reduced, the less moisture will the seedling require.

The investigations carried out clearly showed that seedlings in long grass transpire less, and lose less moisture by evaporation, than those not so protected. Consequently such seedlings require relatively less water than similar seedlings in areas not clothed with grass, or from which the grass has been removed, and *à fortiori* have a greater chance of survival.

We can carry this point further. The more the seedlings are exposed to the direct rays of the sun, and the scorching hot winds of the dry season, the more will they transpire, and the more moisture will they require. Consequently, if in addition to the protecting growth of grass, the seedlings also have overhead cover, we might expect it to act in a similar manner. And this is exactly what we have observed. Wherever the seedlings have been protected by a growth of grass and overhead shade, they have survived in far greater numbers than those in free and exposed positions.

We are of opinion, then, that the amount of shade and cover afforded to the seedlings, in combination with the absolute quantity of water in the sub-soil, are the main factors affecting the survival or disappearance of any Anjan seeding.

We will next endeavour to show how the above theory can be made to fully explain the present condition of our Anjan forests.

(3) FORMATION OF THE PRESENT ANJAN CROP.

(a) *Pure Forest.*

(*i*) *Present conditions.*—We have already remarked on the almost universal absence of natural regeneration in these forests, yet, at some time or other, there must have been such regeneration, to produce the present crop. The question arises, in what way are the present conditions different from those that previously existed ?

In the first place we know for a certainty that all these forests were considerably denser in the past, and that years of unrestricted and unregulated fellings have sadly devastated and opened them up. Further we know that the Anjan has always been very much sought after, and persistently lopped and pollarded, on account of the value of its foliage as fodder. Here then we have two processes at work retarding reproduction, inasmuch as the forest no longer continues to afford the same amount of shade and protection to the young seedlings as formerly, during those critical months of the dry season, with the result that seeding after seeding perishes wholesale, instead of a portion of it surviving to aid in the work of reproduction. If we bear in mind that these pure forests are mostly situated on dry and shallow soil, where the struggle of the seedling for existence is severest, the harm done by depriving it of this most necessary covering becomes all the more serious.

To the above we can now add the factor of grazing. Certainly in Nimar, in those areas most conspicuous for a total absence of regeneration, the grazing is now-a-days very much heavier than it used to be.

Since according to our theory a growth of grass benefits the seedling, grazing must obviously be considered injurious, in removing this protective covering.

Taking now these three conditions together—(*i*) a poor shallow soil, (2) insufficient overhead shade, (3) removal of the protective growth of grass by grazing—we fully believe that the combined effect of these has been, and is, sufficient to account for the present absence of regeneration in forests of the pure type.

The state of affairs to-day can be seen by anyone who will take the trouble to notice the result of a gregarious seeding of Anjan in forest of this type, comparing areas heavily grazed with areas closed to grazing. Nowhere was the present process more evident than in the forests of the Khandwa Range, Nimar Division, after the seeding of 1905. Our

present system of management has given us contiguous areas, respectively, open and closed to grazing.

When the rains of 1906 commenced, the almost total disappearance of the seeding from the areas which were open to grazing, as compared with those closed, was most remarkable.

A very noticeable fact repeatedly observed in these forests is, that wherever a stray seedling exists that has escaped the general holocaust of its brethren, it is to be found under the shelter of a bush of some other species, more often than not one of a thorny nature, such as *Acacia Catechu* or *Gymnosporia montana*. The escape of such a seedling is obviously due to (1) the overhead shade, (2) being protected by the bush from damage by cattle.

Plate F shows a typical example of an Anjan sapling, which has survived and developed under such circumstances.

(*ii*) *Past conditions.*—On the other hand, so long as (1) overhead shade was sufficient, (2) the protective growth of grass was not removed by grazing, the Anjan seedlings were able, in spite of the poor soil, to survive the first critical stages of their existence, producing as a result the present crop.

(*b*) *Mixed Forest.*

(*i*) *Present conditions.*—We are here dealing for the most part with Anjan on sandstone, and granitic formations. The forests of the Punasa and Chandgarh Ranges, Nimar Division, may be taken as the type of this class.

The first point to notice is that, according to Mr. Fernandez, for the 7 years between 1874 and 1881 whilst he was in charge of these forests no Anjan seedling survived, and that, generally, natural reproduction in this type of forest is no better than that on the trap formation. Here, however, we must emphatically disagree. During our frequent inspections of these forests, and whilst wandering in the pursuit of game, we frequently came across areas which would not have been visited otherwise, in which the most perfect advance growth of Anjan was to be seen. Patches varying from half to one and sometimes two acres in extent are not infrequent in these areas. Plate G represents a typical patch of advance growth in the Punasa Reserve on crystalline sandstone, the soil consisting of 8½ inches of sandy loam.

These patches of advance growth, judging from the height of the individual plants, vary in age from a few years up to 20 or more. It

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ANJAN SAPLING PROTECTED BY A KHAIR (ACACIA CATECHU) BUSH.

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cannot therefore be said that there has been no successful natural regeneration, since reservation days, in these forests.

(*ii*) *Factors affecting regeneration.*—Such as it is the existing reproduction can, we believe, be explained in almost every instance by a fortunate combination of (1) suitable soil, (2) sufficient overhead shade, (3) freedom from grazing.

Let us consider for a moment to what extent these three factors have been at work in these forests. Taking suitability of soil, there is no doubt that the sandstone, conglomerate and shale formations are considerably more fissured than the trap formation, and offer more opportunities for the necessary downward development of the tap-root.

As regards overhead shade, these mixed forests are as a rule denser than the pure forests, owing to the competition of other species, and to comparative inaccessibility and lack of demand.

(*iii*) *Harmful effect of grazing.*—We now come to the third factor, grazing. Its importance cannot be over-estimated. It is not so much grazing in itself as grazing at a particular period of the Anjan's life, which has done, and is still doing, so much harm. That period is clearly the time occupied by the seedling in establishing itself, roughly an interval of five years. This being the case, it is not difficult to explain why, in these forests, we have regeneration in some places and not in others. It is a fact that, owing to their extent, the grazing in these forests is extremely irregular in intensity. Into some parts the cattle are brought in large numbers, into others hardly a single animal ever comes, although open to grazing. Even this state of affairs is not constant, and for one reason or another, an area which was formerly heavily grazed over is deserted, and a less frequented part becomes a popular grazing ground.

Now suppose a general seeding to occur all over the reserve. In the ungrazed areas, at that particular time, the seeding finds its opportunity, and other factors being favourable, it survives the critical period of its existence and establishes itself. Not so in the grazed areas. Here the protective covering of grass is being constantly kept down by grazing, and, quite apart from the direct damage done by the cattle to the seedlings, they perish from want of the necessary protection against excessive evaporation.

Once the seedlings have established themselves, the effect of grazing is not of paramount importance. The young plants cannot, it is true, grow up so long as grazing is permitted, but they do not die out, and will exist indefinitely until such time as closure to grazing gives them the

necessary chance of asserting themselves. To illustrate what has been said, we will give two examples from the Punasa Reserve to show what has occurred, and what is actually going on at the present time in these forests.

Example I.—In coupe 9 of the Chickdaria Felling Series a large patch of advance growth was observed in December 1906. The soil here consists of a light sandy loam, and the underlying rock of alternate layers of shale and sandstone, very much fissured, and easily disintegrating. The advance growth varied, from bushes barely 2 feet high to saplings of 8 feet, which we estimated to be from 8-15 years of age. The existence of this most perfect reproduction led us to search, on the same area, for the seeding of 1905, but for the most part in vain.

On the other hand, in the adjoining coupe 30, the same seeding was to be found in profusion, more especially where the grass was longest. Now observe the reason.

Coupe 9 was at the time of the seeding open to grazing, whereas coupe 30 was closed. As regards the existence of the advance growth, the explanation is as follows :—

> Coupe 9 is situated in a very remote part of the reserve. Until the year 1895, that is to say, eleven years previously, there was almost certainly no grazing in this area.

In 1895 a forest village was established here, and grazing commenced, at first light, and then gradually more severe. The advance growth which we now see, had, however, already established itself before the grazing commenced, and once established, grazing has been unable to exterminate it, although it shows evidence of constant browsing.

Example II.—In April 1907 coupe 2, Takli Felling Series, was found to contain a large number of Anjan saplings 5-8 feet high, which, judging from the annular rings on the stems, were not more than 18 inches high in 1902.

At the same time they appeared to be of considerable age. Up to the year 1902 this area had been open to grazing, but it was then felled over, and consequently closed to grazing from that year. The inference to be made is clear. The advance growth was already there, but heavy grazing prevented its further development. Immediately the area was closed to grazing, the plants shot up.

We might multiply these examples indefinitely, but the two will suffice.

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ANJAN ADVANCE GROWTH ON CRYSTALLINE SANDSTONE, PUNASA RESERVE, NIMAR DIVISION, C. P.

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This is the sort of thing that is going on now, and has been going on for a long time in all these Anjan forests. It of course varies in degree in different parts. In Berar, in the same type of forest, regeneration is, we believe, more unsatisfactory than in Nimar. More serious denudation of the forests in Berar, and more general and intensive grazing, may well account for this result.

NOTE.—Since writing the foregoing, some fresh sylvicultural notes on *Hardwickia binata* have appeared in the June and July 1909 number of the *Indian Forester*. The notes are by Mr. L. S. Osmaston. It is gratifying to find that our own observations are borne out, in almost every particular, by this observer, more especially with reference to the effect of a growth of grass on seedlings. His notes relating to the coppicing power of Anjan, we have remarked on under their appropriate head. They compel us to somewhat modify our views on that part of the subject, and will influence, to some extent, what we still have to say in the following chapter on the subject of tending.

II.—Tending.

(1) TENDING DURING EARLY YOUTH.

From what has been said, it is evident that the Anjan requires considerable attention during early youth. The seedlings, we have seen, are peculiarly liable to damage. It will be convenient to deal with each element of danger separately.

(*a*) *Protection against External Dangers.*

(*i*) *Drought and hot dry winds.*—These are the deadliest enemies of the Anjan seedling.

To prevent their ravages, as dense a crop as is consistent with the regeneration of the forest should be retained, and grass and undergrowth made use of as nurses, as much as possible.

(*ii*) *Grazing.*—Grazing should on no account be permittted until the seedlings have thoroughly established themselves, which process will take at least five years. Even then it should neither be continuous nor intensive. It may, however, prove useful, for short intervals, in clearing the young plants, which it must be remembered are partial light demanders, of any exceptionally thick growth of grass. It may be used as a form of weeding, but must not be such as to imperil the further development of the seedlings. Young growth, both seedling and coppice, is highly favoured by cattle and deer. Heavily grazed Anjan has a peculiar, thick, bushy appearance, of which an example is depicted in Plate H.

(*iii*) *Weeds.*—Grass and weeds are beneficial in the first stages of seedling growth, and should not be cleared away. After the seedling has become established and the leading shoot is about to assert itself, it may probably assist the seedling if the surrounding growth is removed. This may either be done artificially, or, as has been suggested above, by light grazing.

(*iv*) *Fire.*—The young shoots are easily destroyed by fire, but in the majority of cases a fresh shoot is thrown out from the root column. On only one occasion have we seen seedling growth completely killed by a fire. In this case the seedlings were from one to three feet in height, and were surrounded by a dense growth of long grass. In all probability, the fire was so fierce that the intense heat generated, penetrated below the ground sufficiently to destroy the root column, and prevent recovery.

Special care should therefore be taken to adequately fire protect seedling growth.

(*v*) *Insects and fungi.*—We have not come across any insect damage to young plants. The mature timber, however, often suffers severely from the attacks of a Longicorn beetle, which has recently been identified by Mr. E. P. Stebbing as *Æolesthes holosericea,* Fabr. The matter is of considerable interest, as the same insect appears to attack Sal in the United Provinces.

The following is from Mr. Stebbing's report on some specimens of the larva and perfect insect, collected and forwarded to him by us :—

> "This beetle is the chief Longicorn beetle of the Sal in the United Provinces Terai, and Oudh Sal belt, where it replaces the *Hoplocerambyx spinicornis* sal pest of the Central Provinces and Assam.
>
> "This is the first report I have received of this insect infesting *Hardwickia binata.* Also I do not find that it has been previously reported as present in the Central Provinces."

So far, the insect has only been found attacking stumps and felled timber. The damage caused by it is often considerable. The larvæ attack not only the sapwood, but even the extremely hard heartwood.

The attacks commence as a rule at the beginning of the rains ; consequently any timber felled during the dry weather, and not removed before the rainy season, is almost sure to suffer. Larvæ, in different stages of growth, and perfect insects, have been obtained between the months of October and December.

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HEAVILY GRAZED ANJAN REPRODUCTION.

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The remedial methods to be adopted would appear to be, (1) removal of the timber from the felling area as soon as possible after felling, and in any case before the next rains commence, (2) removal of the bark and sapwood from the timber immediately after felling.

Nothing is known so far regarding the fungoid diseases of Anjan. That fungi do infest the Anjan, is certain from the number of mature trees which are found to be rotten and hollow inside when felled. We have already referred to this fact in an earlier section.

The matter deserves careful attention, for much of our large-sized timber is rendered valueless on this account. Repeated damage to the young plants by fire and grazing, as well as the "dying back" process to which the seedlings are subject, are probably the main causes at work assisting infection by fungi. Consequently, the best remedial measures to be adopted, are those which have for their object the protection of the seedling from damage, and the reduction of the "dying back" process to a minimum.

(*b*) *Preservation of a proper Density of the Crop.*

A young crop of Anjan will seldom be found too dense, in spite of the prolific nature of a general seeding. The struggle for existence is invariably so acute, that the plants are thinned out naturally. Rather the danger is that the crop may be too thin. The preservation of a judicious mixture of other species is to be recommended, in order to maintain the proper density of the crop.

(2) TENDING AFTER EARLY YOUTH.

(*a*) *Thinnings.*

It will seldom happen in the present state of our Anjan forests, and for some time to come, that thinnings will be required. Rather must we aim at preserving and increasing the existing stocking and density, in order to provide the cover necessary for satisfactory regeneration.

The only areas where thinnings are likely to become necessary, in the near future, are in some of the larger patches of advance growth, such as are found in the Punasa Reserve already alluded to. Here the Anjan tends to oust all other species, and form pure forest. It would be advisable, in such cases, to remove such Anjan as are interfering with the natural development of other species, in order to maintain a judicious mixture. Pure Anjan forest is not to be recommended, even on the better class soils.

(3) REGENERATION.

In deciding on the best method for regenerating our Anjan forests, we must be guided by such considerations as soil, climate, external dangers, and the sylvicultural habits of the species.

Planting we can rule out at once as quite unfeasible.

Direct sowing by itself is costly, and the necessary seed may not be always available.

Generally speaking, we may say that conditions of soil, climate, and cost, as well as past experience, point to artificial regeneration, by itself at any rate, being out of place.

This brings us to the two chief methods of natural regeneration, which will be dealt with separately.

(a) Natural Regeneration by Shoots.

We take this system first, as it is that which, so far as we are aware, is at present in force throughout all our Anjan forests. In theory the system in force is a combination of natural regeneration by seed, with regeneration by stool shoots, known as coppice with standards, but in practice we are almost wholly dependent on coppice regeneration, since the demands of grazing, and the lack of sufficient cover, render it impossible to make use of any but the smallest portion of a gregarious seeding.

In view of the fact that recent observations have shown that the coppicing power of Anjan is by no means so great as has generally been supposed, the present system is not, to our mind, the best suited to the sylvicultural requirements of the Anjan, and should either be entirely given up, or, if other considerations render this impracticable, should be so modified as to ensure the stability and continuance of our Anjan forests.

(b) Natural Regeneration by Seed under Shelter-woods.

We have little doubt that this is the method most suited to the sylvicultural requirements of Anjan. The precise manner in which the regeneration may be effected, may vary according to the soil and locality, but one of the following two methods will be found to suit most cases :—

(1) Group system.

(2) Selection system.

A few words on the merits of each system will not be out of place.

(*i*) *Group system.*—This system is particularly suitable to the mixed type of Anjan forest, on the better class soils such as sandstone, owing to the prevalence of patches of "advance growth."

The groups should be numerous and small to begin with, the necessity of ample cover for the seedlings being duly borne in mind when enlarging the groups.

(*ii*) *Selection system.*—This system is more suitable on poor shallow soil, as on the trap formation, and in the pure type of Anjan forest. Also, where the crop is already very open, and the soil requires special protection.

(c) *Combination of natural regeneration by seed, and by shoots, with artificial formation.*

The first two methods necessitate complete control over all grazing, throughout the areas where these methods are in force.

As such control is not always possible, it follows, that some other system must be devised to take their place in such areas.

For this reason, and this alone, the above system is recommended. In itself, we are convinced it does not do justice to the sylvicultural requirements of the Anjan.

Its chief drawbacks are, (1) that it does not give sufficient shelter to the young seedlings, (2) that the regenerative power of Anjan stools is comparatively poor.

To overcome these drawbacks as far as possible, and prevent the forest deteriorating, it is absolutely necessary that natural regeneration by seed should be supplemented by artificial formation, and this may be best done by sowings. Under the system most commonly in force in the Central Provinces these sowings would be carried out in coupes immediately after they had been felled over, as such areas are then ensured to closure from grazing for a period of ten years.

It is recommended that the sowings be made in patches, as in this way better use can be made of the available cover, without which such sowings are almost bound to result in failure.

The seed does not require to be covered over, but the soil may with advantage be wounded beforehand.

In addition, the proportion of standards to be retained must be the maximum admissible, having regard to the proper development of the coppice. The greater the number of standards, the more protection will there be for the seedlings, and in consequence the greater their chance of survival.


NIMAR
Scale 1 Inch = 12 Miles.
Nerbudda R.
Chandgarh Reserve
Punasa Reserve
Mandhata
Mortakka
Punasa
Chandgarh
Balri
HARSUD
Beria
KHANDWA RANGE
Mundi
Singaji
Kirgaon
Chota Tawa R.
KHANDWA
Bhamgarh
KALIBHIT RANGE
Piplod
Sukta R.
CHANDNI RANGE
Mandwa
Asirgarh
Chandni
Tapti R.
Samardeo
BURHANPUR
BURHANPUR RANGE
INDORE
KHANDESH
BERAR
REFERENCES.
District Boundary
Govt. Forest do.
Govt. Forest
76°
76° 30'
77°
22°
21° 30'
21°
Reg. No. 4100 E., 10.—H.—700

GERMINATION AND GROWTH OF SANDAL SEEDLINGS.

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Germination and Growth of Sandal Seedlings.

By RAO SAHIB M. RAMA RAO,
Conservator of Forests, Travancore.

INTRODUCTION.

In the Nallamalai hill range of the Kurnool District, sandal occurs naturally in small patches over a limited area south of the Krishna river and about 6 miles north of the Mantralakanama road, extending on the west to Pedda-Cheruvu and on the east to the Chinna-Arutla-Peddachama path passing Thummalabailu. That it should have confined itself to this comparatively small area when there is any amount of land to the east, west and south of this locality apparently suitable for its growth on the Nallamalais is rather curious. Could it be that the introduction of the tree was comparatively recent and that it has spread from the few old trees which are growing in the famous Sreesailum Temple enclosure? This conjecture is not improbable, for the existence of sandal on this plateau was first brought to official notice in 1864 by the late Mr. Sheffield, who then found no trees over 4 inches in diameter. When the writer inspected this sandal area in February 1907, he found no trees exceeding 7 inches in diameter. An investigation into the origin of sandal here would be interesting and perhaps not altogether unprofitable. Sandal is also found in some of the gardens at Cumbum, in a few private compounds at Kurnool and up the canal from the latter place as far as its junction with the Tungabhadra river at Sünkésula. It is said to occur also on the Yerramalai plateau between Betamcherla and Malkapuram, and at and around Rangapuram, along a nulla near Uyyalavada village of Cumbum Taluk, and also near a village about 5 miles west of Nandikotkur town.

2. With a view to introduce this most valuable species into the central Nallamalais where it is believed that natural conditions favourable to its growth exist, some experiments on a small scale were undertaken to study the best method of propagating it. The following is a brief record of the results of these experiments.

PART I.

NURSERY EXPERIMENTS.

Experiment No. 1 at Diguvametta.

3. In October 1905, a small quantity of seed was obtained from the Bellary District. The seed was old and had been collected probably a year previously. One bed in the nursery was sown with sandal seed on the 24th November 1905, and it was watered regularly. On the same date, some seed was dibbled in amidst bushes on the banks of the Sagileru and along the western fence of the teak plantation but these were not watered. Neither in the nursery nor in the dibbled area did any seed germinate for two months. The sowings proved a failure, due most probably to the age of the seed, as in other respects every care and attention were bestowed on the experiment.

Experiment No. 2 at Kurnool.

4. On the 2nd January 1906, a small nursery bed was prepared after digging the soil to a depth of $1\frac{1}{2}$ feet to ensure freedom from roots of other plants in the compound of my bungalow at Kurnool. It was sown with sandal seed collected under a few sandal trees growing on the canal bank and also a few ripe fruit picked off the trees that morning. The bed was regularly watered once a day. Two seeds germinated on 2nd February, 2 more on the 9th, 2 on the 15th, 1 on the 20th and 3 on the 23rd idem; and some were still germinating. On the 28th idem 6 of the seedlings measured $2\frac{1}{4}$ to $3\frac{1}{8}$ inches in height and had 3 pairs of leaves omitting the cotyledons.

In the middle of March 1906, the bed was divided into two by a small bund and in one of them peppermint (Mentha piperita) was planted between the sandal seedlings while the other was left untouched. In June the roots of the sandal seedlings were found to have formed root attachments with the peppermint plant in the one bed while in the other they were unattached and their leaves looked paler than those of the former bed. Gradually the purely grown seedlings became paler and sicklier and all of them died off before the end of December 1906. An examination of their roots showed that rootlets and root-fibres were scanty, ill-developed and unhealthy and the ends of the tap-roots were dead in most cases. Among the seedlings associated with the peppermint plant,

only 4 seedlings were healthy and vigorous and the rest stunted and sickly : the mint plant gradually died out and only the 4 sandal seedlings survived. Of these one close by which a cotton (Gossypium arboreum) plant was vigorously growing showed a rapid growth and measured 33 inches in height early in January 1907 ; two of the others remained small measuring $1\frac{1}{2}$ feet and 9 inches in height while the 4th plant died out. On gently removing the earth round the roots of the best grown plant it was found that it had formed numerous root-connections with the cotton plant. It measured 52 inches in height at end of August 1907. A number of sandal seedlings were growing close to a plantain tree, but I could discover no root-connections between them and the latter : eventually they died off.

In the course of this experiment it was observed that a number of seedlings had been damaged by squirrels, rats and insects, and their stems broken off about an inch above ground in March 1906. The ends of these stumps thickened gradually and adventitious shoots were formed in some cases, while in others the seedlings died. This fact was observed in other experiments also.

Experiment No. 3 at Diguvametta.

5. On the 25th January 1906, a nursery bed was sown with sandal seed collected at Kurnool at the beginning of the month, and watered daily. The first germinations were noticed on the 14th March and on the 22nd idem there were 100 seedlings, and on the 12th April 135 seedlings. About the third week of June, the seedlings were somewhat paler than in April, and this was probably due to the pulling up of the weeds that had come up in the bed, by the gardener, who was ignorant of the root-parasitic habit of sandalwood.

Some of the seedlings were damaged by insects and vermin when they were hardly two months old. A few of the damaged seedlings sent out lateral shoots and survived the damage while the others succumbed.

Taking advantage of a light shower of rain that fell on the 24th June, all the seedlings, of which there were 218, were removed from the nursery with balls of earth on the 25th idem and planted out amidst and close to bushes of other species with a few seeds of *Margosa* (*Melia Azadirachta*) and *Dirsanam* (*Albizzia Lebbek*) so that the roots of sandal might attach themselves to the roots of these species when they germinated. The transplants were regularly watered. On the 3rd of August 1906

there were only 159 plants alive, and on the 25th idem only 141 alive and these pale and sickly: on 29th September the number had dwindled to 101, and the seedlings looked very unhealthy. In the latter part of October there were 33 transplants alive, and on 21st November only 12. In most cases the seedlings of *Margosa* and *Dirsanam* also died. On examining the roots of some sandal transplants I found them unhealthy with very few secondary roots and rootlets and no attachments to roots of other plants. On the 9th January 1907 only 2 transplants were alive and these in a dying condition. Subsequently these too died. The experiment thus ended in failure, not even a single sandal seedling having been established out of the 218 transplanted.

Experiment No. 4 at Diguvametta.

6. In the second week of April 1906, 705 bamboo tubes 2″ to 3″ in diameter and 10″ long with 4 or 5 holes bored in the septum at the bottom node of each to allow surplus water to escape, and 536 pot tiles were arranged honeycomb-wise in the nursery as shown in the illustration Plate X and filled with friable loamy soil up to an inch below the top, the soil being pressed down firmly: water was poured into each to further consolidate the soil. To keep the honeycomb in position, earth was put round them up to the top. In each of the tubes or tile-cylinders, 3 sandal seed and 2 of *Kanuga* (*Pongamia glabra*), *Neeroddi* (*Dolichandrone crispa*), *Odesa* (*Cleistanthus collinus*), *Vepa* (*Melia Azadirachta*), *Dirsanam* (*Albizzia Lebbek*), *Chennangi* (*Lagerstroemia parviflora*), Teak, or Tamarind were put in and watered daily and regularly. None of the sandal seed germinated and only a few *Neeroddi*, *Dirsanam* and *Odesa* sprouted up. On the 23rd June, when the sandal seed was examined it was found to have rotted in every case. I believe the failure of this experiment was due to the stagnation of water in the tiles and tubes the soil in which had become too hard to allow the surplus water to run through, and to insufficient aeration due to the interstices between and round the tiles and tubes having been filled in with earth.

7. On the 23rd June 1906 all the tiles and bamboo tubes were pulled up and after cutting off the nodes of the tubes and splitting each of them into two, they were re-arranged into honeycombs and held in position by bamboos horizontally laid between forked uprights fixed in the ground at the corners of each honeycomb. The tubes and tile-cylinders were lightly filled in with good fresh soil and sown with

Kurnool sandal seed collected in the preceding January and seeds of one of the other species as was done at first in the previous April. Round the honeycombs earth was loosely banked up about 2″ high but the interstices between the tubes or tile-cylinders were left unfilled to facilitate free circulation of air and escape of surplus water. One thousand one-hundred and forty-three bamboo tubes and 405 tile-cylinders were used in this experiment. The honeycombs were watered daily.

The *Dirsanam* seed commenced germinating on the 28th of June 1906, next *Kanuga* on the 3rd of July and Teak on the 6th of July : only a few tamarind and *Odesa* seeds germinated later. The first germination of sandal seed was observed on the 19th of July 1906. On the 29th of September there were 82 sandal seedlings in the tile-cylinders and 95 in the bamboo tubes. There were no germinations in the rest of the bamboo tubes and tile-cylinders. Failures were greater in the former than in the latter, probably due to the narrowness of space in them. The sandal seedlings associated with *Kanuga* were the best and largest, next came those associated with *Dirsanam*, next those associated with *Odesa* and last those with Teak. A number of tile-cylinders and bamboo tubes contained pure sandal seedlings, the seeds of the host plants either not having germinated at all or having died out soon after sprouting.

In the middle of March 1907, some of the best grown seedlings were measured with the following results :—

Sandal with *Kanuga*.	Sandal with *Odesa*.	Pure sandal.
high.	high.	high.
1 Sandal seedling . . . 22″	1 Sandal . . 17″	1 seedling . 7″
1 „ „ . . . 21″	1 „ . . 13″	1 „ 5″
1 „ „ . . . 17″	1 „ . . 10″	both unheathy and pale.
	In above cases host plants stunted and sickly.	All pure sandal seedlings were pale and unhealthy and leaves much smaller than those grown with hosts.
	high.	
	1 Sandal . . . 8″	
	1 „ . . . 7″	
	1 „ . . . 6″	
	In these cases host plants pretty healthy and vigorous.	

For some reason which could not be ascertained, almost all the *Dirsanam* hosts sickened and died. Only in a few cases Teak seedlings survived but were unhealthy. The tiles and tubes containing teak with

sandal seedlings were transplanted in March 1907 in the Teak plantation of 1906, and a few of them were thriving well in August 1907.

In the latter part of June 1907 the three sandal seedlings grown with *Kanuga* were measured again, and the first 2 plants were found to be 43″ and 42″ high respectively, and the third plant, having lost its original leading shoot, had produced two side-shoots measuring 22″ and 21.″

At the end of March 1907, most of the sandal seedlings with their hosts grown in tile-cylinders and bamboo tubes were lifted with their receptacles and planted out in vacant beds of the 1906 Teak plantation, and were regularly watered till the south-west monsoon set in. Some of them died, there remaining only 23 seedlings in the middle of August 1907. All the purely grown sandal seedlings, whether left in the nursery or planted out, died without exception, their root-ends having decayed.

The transplanted seedlings were measured on the 16th August 1907, and the following results were recorded :—

Sandal with *Kanuga*.	Sandal with *Kanuga* and teak.	Sandal with *Kanuga* and *Odesa*.	Sandal with *Odesa*.
high	high,	high.	high.
1 seedling 51½″	1 seedling 23½″	1 seedling 33½″	1 seedling 21″
1 ,, 37″	1 ,, 20″	1 ,, 8″	1 ,, 10″
1 ,, 24″	1 ,, 16″		
1 ,, 21″	2 ,, 10″		
1 ,, 19″			
1 ,, 18″			
1 ,, 15″	In these cases Kanuga was planted some time after transplanting the sandal as the latter showed signs of withering, probably owing to the sickly condition of their original hosts		
2 ,, 14″			
1 ,, 13″			
4 between 9½″ & 5″			

All the sandal seedlings appeared healthy and vigorous on the 15th August 1907 and were doubtless well established.

8. Some of the seedlings with their hosts were taken up and carefully washed at the end of October 1906, they were found to have established root-connections with the hosts. In all cases in which sandal seedlings were vigorous, the haustoria were somewhat larger, more numerous and healthy : thin and long thread-like rootlets were more numerous and largely developed in the young sandal with their ends slightly thicker, reddish-brown and pointed — a characteristic which enables us to distinguish the sandal rootlets from those of its hosts in many cases ; whereas in cases in which the sandal seedlings were stunted unhealthy and

withering, the haustoria were smaller and less numerous, and secondary and tertiary rootlets were fewer and shorter.

It may not be out of place to mention that in numerous cases of young thread-like rootlets of sandal seedlings and of their hosts the haustoria were found developed on the sandal rootlets themselves even when actual attachments had occurred, instead of on the hosts' rootlets as generally occurs in more developed and thicker rootlets: in some instances, thin rootlets of host plants were found trailing along those of the sandal and firmly fixed to them at some points without any visible haustoria being formed at such points, while in others the sandal rootlets trailed along those of the hosts.

Experiment No. 5 at Diguvametta.

9. On the 19th July 1906, two dealwood boxes A and B were divided into two equal compartments by fixing a plank vertically in the middle. In box A, one compartment was filled with sand and the other with loamy friable soil from the nursery. In the former 184 sandal seeds and in the latter 130 were sown. In box B one compartment was filled with sand and the other with loamy soil: the former was sown with 200 sandal seeds and 200 *Dirsanam* (*Albizzia Lebbek*) seeds, and the latter with 200 sandal and 200 *Kanuga* seeds (*Pongamia glabra*).

In both the boxes and in all the compartments germination of sandal was observed on the 16th of August. On the 29th of September, there were 46 sandal seedlings in the sand and 8 seedlings in the soil compartments of box A; in box B, there were 30 sandal seedlings in the compartment sown with *Kanuga* and 36 sandal seedlings in the other. The *Kanuga* and *Dirsanam* seedlings which had also germinated were not counted. The sandal seedlings in all the compartments were alike in their vigour and appearance in September 1906.

On the 16th of March of the following year the heights of the seedlings were measured and the following notes recorded:—

Box A.— Pure sand.	Average height of 20 seedlings was 6″.	Plants fairly healthy.	Leaves light-green and small.
Pure loam.	Average height of 8 seedlings 7″.	Not quite so healthy.	Leaves slightly blanched and pale-green, small and narrow
Box B.— Sandal and *Kanuga.*	Average of 3 big sandal seedlings 15″ and a large number 12″ high.	All healthy except those suppressed by host plants.	Leaves dark-green and larger.
Sandal and *Dirsanam.*	Average of 14 big seedlings 8″ and of a number 5.″	All healthy except those suppressed by host plants.	Leaves dark-green but somewhat smaller.

The host plants in both compartments were healthy along the outer margin and measured up to 16″ high; but in the interior, they were stunted and small-leaved and measured less than 7″ high.

On the 20th of June the sandal seedlings in all the compartments were again measured with the following results :—

Box A.— Pure sand	There were 18 seedlings of which 9 dead: tallest plant was 7″ and smallest 4″ high.	All plants unhealthy and dying.	Leaves had dropped off except the topmost pair or two and these very narrow and yellowish and withering.
Pure loamy soil.	There were 13 seedlings of which 5 dead: height varied 9″ to $3\frac{1}{2}$″.	All plants unhealthy and dying except those growing close to weeds which had spontaneously come up in the box.	Leaves had dropped off except of plants near weeds which were pale-green and larger.
Box B.— Sandal with *Kanuga.*	There were 29 sandal and 9 *Kanuga* seedlings. 11 sandal and 6 Kanuga were dominated or suppressed by others.	Tallest sandal 33″ and smallest 15″ high.	Leaves large and dark-green: plants branched from axils above their middle, except dominated ones whose leaves were smaller and yellowish and no axillary branches.
Box B.— Sandal with *Dirsanam.*	There were 37 seedlings (of which only one dead) and 25 *Dirsanam* plants. 12 sandal plants were dominant and rest dominated or suppressed by the host plants.	Tallest sandal 19″ and smallest 7″ high.	Leaves large, healthy and green in dominant seedlings: small and pale in dominated ones: no axillary branches on any of the seedlings.

The surviving seedlings in box A were irretrievably decayed and were therefore removed after carefully washing out all soil round their roots and then dried and preserved as specimens. Those in box B were sent to Waltair with the box itself intact for transplanting in the forest garden of the Conservator's Bungalow. They were reported to be thriving well about a fortnight after transplantation, but afterwards died from the *malis* foolishly digging about their roots.

The process of germination.

10. In all the above experiments the soil was well triturated and levelled in the nursery beds, tile-cylinders and bamboo tubes, and the

seeds of sandal and of host plants were sown and covered with a thin layer of soil in no case exceeding the thickness of the sandal seed. They were watered daily except in rainy weather when there was sufficient moisture. To drain off surplus water, a small trench was dug on the lower side of the nursery bed.

The earliest germination of sandal in one case was on the 27th day, in another on the 29th day, in the third case on the 31st day and in a fourth case on the 49th day after sowing. The observation in the last case was recorded by a Ranger, and the accuracy of his observation appears doubtful as it differs so enormously from the periods of germination in the other three cases. For practical purposes we may assume one month as the earliest period for sandal seed to germinate. I have observed germination to continue even up to the end of the third month after sowing.

Some days after sowing, the seed swells a little and the radicle develops first and the seed-shell cracks near the radicle, thus allowing the latter to push forward and enter the soil downwards : then the hypocotyl develops and forms a loop which becomes thicker and longer and rises above the ground : meanwhile, the radicle grows rapidly downwards and becomes firmly fixed in the soil. Then the loop unbends and the hypocotyl becomes erect, crowned at its top by the seed-shell : the cotyledons also develop rapidly, though still covered by the seed-shell : the plumule pushes itself up vertically between the cotyledons and out of the seed-shell which still continues to envelope the cotyledons whose petioles have also emerged out of the seed-shell. When the cotyledons develop and expand to their full size, the seed-shell drops off naturally. But very often insects attack the cotyledons before they are fully developed and nip them off leaving their remains on the young stem for a considerable period. In a young germinating seedling the taproot (radicle) which had not yet developed any lateral rootlets, measured 1 $\frac{9}{16}''$ long while the hypocotyl along the curve of the loop was only $\frac{3}{4}''$ up to the base of the cotyledons. The length of the cotyledons was $\frac{9}{32}''$, while the plumule was only $\frac{1}{32}''$—a mere elongated speck. The cotyledons were yellow at their apex and green at their base. When the loop unbends and stands erect the well-known " raddish-like " appearance of the hypocotyl becomes distinct. Specimens illustrating these points have been drawn; from an examination of them it will be seen that the plumule has emerged out of the seed-shell, while the upper portion of the cotyledons remains still enclosed in it. See Plate II.

A few seedlings raised from seed sown pure on the 2nd of January 1906 at Kurnool were measured on the 28th of February and the results are recorded below :—

Number of seedling.	Date of germination.	Length of seedlings up to tip.	No. of pairs of leaves.	REMARKS.
1	2nd February 1906	$2\frac{3}{8}''$	3	3 leaves at each of the first 2 nodes and 2 leaves at the 3rd node.
2	,,	$3\frac{1}{8}''$	3	Only 2 leaves at each node.
3	9th February 1906	$2\frac{7}{8}''$	3	
4	,,	$2\frac{1}{4}''$	3	
5	15th February 1906	$2\frac{1}{4}''$	3	
6	,,	$2\frac{7}{8}''$	3	

N.B.—The terminal bud and cotyledonary leaves were not reckoned in counting pairs of leaves.

After this stage the height-growth was not measured till January 1907 when there were only 3 seedlings surviving, and they measured 33,″ 8″ and 9″ respectively. Judging from the results of the foregoing experiments, it appears that the rate of height-growth is largely dependent upon the species of host plants associated with the sandal seedlings, apart of course from the innate vigour of the latter themselves derived from the reserve material in the seed.

11. *Explanation of the accompanying plates.*

Plate I.—Specimens of sandal seedlings picked up under a sandal tree in Denkanikotta Forest Office compound. Seedlings grown naturally from seed shed by the parent tree.

FIG. 1.—A germinating young loop of sandal seedling with radicle and hypocotyl partly developed : plumule and cotyledons still enclosed in the seed cover : end of radicle broken.

a a side rootlet just forming with a reddish-brown and pointed end.

FIG. 2—A young seedling with loop just becoming erect and taproot much longer and better developed.

aaa secondary rootlets just forming with the characteristic reddish-brown tips—a pebble was attached to the rootlet on the right side of the lowest *a*, but it dropped off on moving with a pin.

h a haustorium.

The cotyledons and plumule which had been still enclosed in the seed-shell dropped off.

FIG. 3—A seedling about 2 months old.

Secondary roots and rootlets are well formed.

c remains of the petioles of cotyledons.

hhh haustoria.

Plate II.—Specimens of germinating sandal seedlings picked up at Denkanikotta along with those in Plate I.

FIGS. 1 AND 2—Illustrate emergence of the growing point (plumule) from the seed-cover, while the latter still encloses the cotyledonary leaves whose petioles have partly emerged out of it. Note the 3 cotyledons in specimen No. 2—not an uncommon occurrence in sandal.

FIG. 3—Shows the stage at which the seed-cover has just dropped off. In all the specimens *cc* indicate the cotyledons and *ppp* the plumule (growing terminal bud).

Plate III.—Specimens of 4 sandal seedlings grown pure (unmixed with other species), in the nursery at Diguvametta between June 1906 and June 1907. All the seedlings illustrate scanty development of roots and rootlets, and stunted and unhealthy growth of leaves, and hence early decay resulting in their gradual inanition and death is indicated. Examination with a lens shows a few attachments to foreign rootlets *fr.* of weeds and minute haustoria formed on the sandal roots themselves *h*.

Plate IV.—Specimens of 2 sandal seedlings A and C 4 months and 4 days old, and of a weed (*B*) which was growing with one of them (*A*) : these illustrate the abundant development of fine thread-like roots and rootlets from the sandal roots and their pointed

reddish-brown ends which appear characteristic of sandal. An examination with a lens shows numerous haustoria (*hh*) on the sandal rootlets themselves, and their actual attachments to roots of the weed at (*f*) and (*g*) ; the former (sandal rootlets) can be distinguished from those of the weed by their brighter white-brown colour and reddish-brown tips ; (*d*) and (*e*) are fine sandal rootlets of seedling A detached during examination ; *fr*—foreign roots ; (*c*) remains of the petioles of cotyledons.

Plate V.—Specimens of sandal and *Kanuga* (*Pongamia glabra*) seedlings grown together in tile-cylinders, A, B and C being sandal seedlings, and D and E *Kanuga* seedlings ; seeds sown on the 25th of June 1906, and seedlings taken out on the 29th of October 1906. Examination of the network of sandal and *Kanuga* rootlets with a lens will reveal numerous haustoria (*hh*) and attachments between the rootlets of both species. Note the vigorous and healthy growth of the sandal seedling B compared with those in Plate IV and suppression and consequent stunted growth of the seedling C : the tap-roots of *Kanuga* have also been attacked by the sandal rootlets and haustoria are formed on them. The secondary and tertiary roots of *Kanuga* are not as abundant as those of the same species grown in nursery beds, probably owing to the limited space in tile-cylinders in which these specimens were raised.

Plate VI.—Specimens of sandal and *Dirasanam* (*Albizzia Lebbek*) seedlings grown in tile-cylinders ; seeds sown on the 25th of June 1906, and seedlings taken out on the 29th of October 1906. Root-connections between the 2 species and the numerous haustoria (*hh*) are found in both sets of the specimens. The height-growth of the sandal seedlings is much less than that of the seedling B in Plate V, and the root development of the host plant is not so abundant as that of *Kanuga* : this may partly account for the comparatively slow development of the sandal seedlings.

Plate VII.—Specimens of sandal (*A*) and *Odesa* (*B*) & (*C*) (*Cleistanthus collinus*) seedlings grown together in tile-cylinders : seeds sown on the 25th of June 1906, and seedlings taken out on the 29th of October. Root-attachments between both, and haustoria (*hhh*) of sandal are found not only in the network of rootlets but also on the tap-root of the *Odesa* plant close to the sandal seedling ; note the stouter secondary and tertiary rootlets of Odesa plants and the larger size of the sandal seedling and its leaves than in the case of other host plants.

Plate VIII.—Specimens of sandal (*A*) & (*B*) and teak (*C*) & (*D*) seedlings grown together in tile-cylinders : seeds sown and seedlings taken

out on the same dates as those in the above plates. Careful examination with a lens of the network of rootlets shows some root-attachments between the 2 species, but they are not so numerous as in the other cases ; one of the teak seedlings sickened and was withering when removed from the tiles pots. The sandal seedlings in both specimens were healthy though not quite so vigorous and rapid in growth as those grown with *Kanuga* or *Odesa*. *s. h.*—Scar of Haustorium.

Plate IX.—Specimens of 2 sandal seedlings growing together pure in one tile-cylinder. Their roots have mutually attacked each other and formed connections at several points starting from *a* of the seedling on the right-hand side. Note the scanty and short development of the secondary and tertiary rootlets as well as the shortness of the tap-roots of both seedlings compared with those grown with other species of plants (Plates IV to VIII).

Plate X.—A diagram of the tile-cylinders arranged honeycomb-wise.

12. Summary of the results gathered from the foregoing experiments.

1. Sandal seed appears to lose its vitality in about a year and apparently does not germinate after this period. (This point requires further investigation and confirmation as it is based on only one experiment.)

2. It generally germinates in about a month after sowing and germination may continue up to 3 months and even later.

3. The seed-bed should be well drained as otherwise stagnant water will cause the seed to rot more easily than in many other species.

4. The young seedling is nourished and developed almost solely by the reserve material in the seed in its early stage : the reserve material is transferred quickly to the hypocotyl from the cotyledons, which, however, persist for a long time (6 months or more) on the young stem, unless destroyed by vermin as often happens.

5. Sandal seedlings are incapable of growing beyond a year at the most unless nourished by root-attachments to roots of other plants without which they turn pale, wither and die out within a year of germination.

6. Young seedlings establish root-attachments with other plants at a very early age – when less than even 2 months old. (Examination of the roots of a number of young sandal seedlings with a strong lens showed that root-hairs and root-fibres which are the chief organs of absorption

of nourishment from the soil were much fewer and less developed than in the seedlings of non-parasitic plants.)

7. In sandal seedlings grown pure side-roots (secondary and tertiary) are small, poorly developed and scanty, and root-ends decay and die down, whereas in seedlings growing with other species they are more abundant, longer and healthier.

8. Seedlings grown pure do not thrive when transplanted even with balls of earth in which they grow in the nursery and even when they are planted close to the seedlings of other species. (This inference is based upon the results of only one experiment and therefore requires further investigation.) This may probably be due to the inability of sandal roots to reach and attach themselves to the roots of the host plants, owing to the scanty development of their root system.

9. Sandal seedlings raised with seedlings of other species, the seeds being mixed at the time of sowing are more successful, healthy and vigorous.

10. Although the sandal plant may attack roots of almost any plant, it shows a decided preference for some species, in whose company it grows best; for example, in the above experiments, *Pongamia glabra* and cotton plants (*Gossypium arboreum*) have been found to be the best; next *Albizzia Lebbek*; next *Cleistanthus collinus* and so on.

11. For transplanting purposes the best method of raising sandal seedlings in a nursery is to sow the seed with that of the host in tile-cylinders above the ground and to remove and plant out the whole cylinder, thereby causing the least disturbance and damage to the roots and their attachments: basket-cylinders may prove as good as tile-cylinders but they are liable to destruction by white-ants or by rotting.

12. The tile-cylinders may be transplanted when the sandal seedlings are 4″ to 6″ high: bigger plants up to 2′ high have been transplanted successfully, but their roots are liable to injury when lifting in the nursery, especially when they have attached themselves to foreign roots at the bottom of tile-cylinders as usually happens.

13. The transplants require to be watered gently but copiously until they are well established.

14. If the host plants show signs of exhaustion or decay, other vigorous hosts should be planted at once close to the sandal seedlings without disturbing and damaging their roots.

15. Transplanting close to or amidst suitable host plants already existing on the site would be conducive to quicker and more vigorous growth of the sandal.

PART II.

Experiments on in-situ *sowings of Sandal.*

13. A bag of fresh sandal seed was kindly supplied by the District Forest Officer of North Salem. This was sown mixed with seeds of *Dirsanam*, *Vepa* and *Kanuga* in several places in the Railway Working Circle and at the Chenchu centres at Maddipenta, Chinna-Mantrala and Pedda-Mantrala. The mode of sowing was this. A number of women each carrying a small quantity of the mixed seeds and a blunt pointed stick made shallow holes with the stick under bushes and dropped in each hole a sandal seed with seeds of host plants a few inches apart in each patch. Thus at every spot or patch 2 sandal, and 2 *Vepa* or 2 *Dirsanam* or 2 *Kanuga* seeds were sown and lightly covered over. The sowings were done in July and August 1906 on or immediately after rainy days. The bushes under which the sowings were made consisted of such species as are generally found in the natural *habitat* of sandal, viz., *Zizyphus*, *Randias*, *Webera*, *Limonia*, *Toddalia*, *Murraya*, *Acacias*, *Pterolobium*, *Albizzias*, *Pongamia*, *Melia*, Bamboos, etc.

14. The following are the localities at which the sandal sowings were made in 1906 :—

Railway Working Circle.

Locality.	Date of sowing.	Quantity of mixed seed sown.
(1) Diguvametta—Along the Sagileru river on both banks from Railway bridge up to first crossing of the old road to Malakondapenta.	Latter part of June and July 1906.	6¼ seers of sandal and 6¼ seers of *Vepa* and *Dirsanam* mixed.
(2) Diguvamatta—Amidst bushes in horse-gram area north of 1905 Plantation.	July 1906 .	......
(3) Tungapenta—Along the Digutisela stream for 1½ miles.	" .	6½ seers of mixed seed.
(4) Tungapenta—Along the Dadigundalu stream for about 1½ miles.	" .	5½ "
(5) Chelama—Near Dongabhavi .	30th June 1906.	¾ seer sandal with 1½ seers of *Vepa*, *Dirsanam* and *Chinduga* (*Albizzio Odoratissima*).

Railway Working Circle—contd.

Locality.	Date of sowing.	Quantity of mixed seed sown.
(6) Chelama—On Rampakothakosina Konda north-west of rest-house.	July 1906 .	$4\frac{3}{4}$ seers of mixed seed.
(7) North of the Chelama new tank .	,, .	$10\frac{1}{2}$,,
(8) Bhireni —On Mondikatta . .	,, .	3 ,,
(9) Palerdam—West of Railway guide line between Chelama and Palerdam.	,, .	2 ,,
(10) Palerdam—On Muduguddalavagu .	,, .	3 ,,
Cumbum Range.		
(11) Maddipenta—North of the first year's plantation and East of Chinna-Mantrala road.	......	......
Markapur Range.		
(12) Chinna-Mantrala—Near Camping ground.	......	......
(13) Along Kortikanama path, in patches at three places west of Camping ground.	......	......
(14) Pedda-Mantrala—West of the Plantation of 1905 amidst bamboo bushes.	......	......

15. The sowings along the Sagileru and in the horse-gram area near Diguvametta were the most successful, because the operations were conducted under the frequent personal supervision of the District Forest Officer and of two Rangers (Rahimtulla and Chengappa); the sowings elsewhere in the Railway Circle were entrusted to Foresters and Deputy Rangers under the supervision of Ranger Chengappa who did not pay as much personal attention to them as he should have done. The sowings in the other Ranges were conducted by the Deputy Rangers in charge of the Chenchu *Gudem* works, under the supervision of Extra Assistant Conservator Mr. G. W. Thompson. Germinations of sandal along the Sagileru and in the horse-gram area were first observed in the second

week of August 1906. On the 29th September there were 212 sandal seedlings along the Sagileru and 30 seedlings under bushes in the horse-gram area as reported by Ranger Chengappa. They were all healthy and vigorous. In the third week of June 1907, I inspected this area and made a partial counting of seedlings here and there and found 150 sandal plants all healthy and vigorous and some of them more than 1 foot high. I then recorded the following remarks in my diary for the week ending 22nd June :—"Considering that the sowings were not watered at all and that we have done nothing more for them than protecting them from fire and cattle, I think the results very satisfactory and encouraging. These seedlings may be taken as established as they have survived one hot weather: even if damaged by deer and other wild animals, they are not likely to disappear hereafter, provided they escape fire."

On 16th August 1907 Ranger Rahimtulla measured 20 seedlings at random with the following result :—

1	Sandal	seedling	24"	high.
1	,,	,,	23"	,,
2	,,	,,	16"	,,
2	,,	,,	15"	,,
1	,,	,,	14"	,,
1	,,	,,	13"	,,
4	,,	,,	12"	,,
1	,,	,,	10"	,,
4	,,	,,	9"	,,
1	,,	,,	8"	,,
1	,,	,,	7"	,,
1	,,	,,	4"	,,

These seedlings do not compare unfavourably in their height-growth with those of the same age raised in the nursery with their hosts in tile-cylinders, excepting 2 or 3 sandal seedlings grown with *Kanuga* and which had a marvellously rapid height-growth—*vide* the results of experiment No. 4 described under Part I. In their vigour and general appearance of health these *in-situ-sown* seedlings were quite equal to and in some cases better than nursery-raised seedlings—notwithstanding the regular watering and constant attention these latter received, while the former received no watering during the hot weather and no more attention than protection from fire and cattle.

The sown area was frequently grazed over by large herds of deer especially at night in spite of its having been fenced with thorns, and a large number of seedlings were damaged or destroyed. Notwithstanding this damage, the number of plants now surviving must be very much larger than what the subordinates have counted, as it is improbable that they noticed all the sandal seedlings amidst the dense growth of rank vegetation along the Sagileru.

16. Information available regarding the results of the sandal sowings in the other localities is meagre and incomplete, and the following brief remarks are based on what I saw when I last inspected some of the localities.

Chelama.—Dongabhavi sandal sowings.

On 1st September 1906 there were 14 sandal seedlings with an average height of about 4″ : overgrown with grass and weeds which were subsequently cut and removed : the area had not been properly protected, it was therefore fenced later on.

Sowings North of the Chelama Tank.—Inspected on 1st September 1906, and found a few sandal seedlings. Sowing was done in cleared patches which was a mistake. Some of the seedlings healthy : they were of the same average height as those at Dongabhavi. As the area was unprotected, orders were issued to fence it with thorns to keep out cattle and wild animals.

Sowing near Tungapenta.—Inspected on 28th October 1906 : a number of sandal seedlings were found east of Tungapenta sheds on the right bank of the stream and in another patch south of the Railway line and west of the station buildings: the seedlings were healthy and some of them were about 5″ high. Forester was ordered to fence them.

Sowing near Maddipenta.—Inspected on 2nd August 1907 and could trace out only 2 sandal seedlings which were not healthy : the area selected was unsuitable owing to heavy cover of bamboos and tree-growth overhead and a dense covering of leaves on the ground, causing heavy drip from above and damp below with insufficient admission of light: there were few or no young plants of species suitable as hosts for the sandal on the ground. A number of seedlings germinated but all of them died off owing to damp and drip, only the 2 seedlings surviving.

Sowing near Chinna-Mantrala.—Inspected on 5th August 1907, and found 4 sandal seedlings on the west side of the Camping-ground on the

bank of the nulla : they were healthy and vigorous and above 6″ high, the patches had been fenced : a large number of seedlings had germinated but died in the hot weather for want of water, there being no water anywhere within 2 miles of the Chenchu *gudem*.

On the Kortikanama path, about a mile west of the Chenchu *gudem* I found 6 sandal seedlings in the patch sown in 1906. Four of the seedlings were healthy and the other two somewhat sickly. These also had been fenced in with bamboos.

Sandal near Pedda-Mantrala.—Inspected on 8th August 1907 : the area sown with sandal in 1906 is to the west of the plantation of 1907 and the dibbled area of 1906 : the sandal was sown in a low bamboo area on both sides of a small nalla that runs into the Pedda-Mantrala tank. I found only 6 sandal seedlings all healthy and vigorous. One of the plants was 2 feet high and had branched, the rest were about a foot high. They had not been properly fenced and a fence was therefore ordered to be put up at once. Here, too, there were not many bushes of species suitable as hosts for sandal, probably owing to the heavy cover of the somewhat low bamboo clumps. In this locality also a large number of seedlings died, probably owing to damp and drip during the rains and the heat of the succeeding hot weather. The locality appears better suited for sandal than Maddipenta, provided the heavy bamboo cover is partially opened out and *Kanuga* and *Dirsanam* are introduced as hosts.

17. The sowings at the last three places would have proved more successful, had the Deputy Rangers in charge of those Chenchu centres paid any attention to them, but owing to sickness and frequent changes of officers, the sowings were neglected. The localities being in the heart of the Nallamalais and better suited for the growth of sandal than Diguvametta where the experiment may be said to have been successful, I think attempts to sow sandal with frequent inspections and protection from fires, cattle and wild animals, will succeed in establishing and spreading this valuable species, if these attempts are persisted in.

Sandal sowings of 1907.

18. Having received a large supply of sandal seed from the North Salem District, it was distributed to all the Ranges except Rachakonda in the East Kurnool District in order to sow it with seeds of *Kanuga, Dirsanam, Yegi* (*Pterocarpus marsupium*), etc.

Sowings were commenced under my personal supervision at Diguvametta in the latter part of June and July and about 60 acres were sown in the whole of the horse-gram area, in the old teak dibblings of 1905 and along the Sagileru. In the middle of August 1907, I saw seedlings germinating in these localities.

On 5th August 1907 Mr. Aswatham Naidu and myself personally supervised dibblings of sandal with *Kanuga* at Chinna-Mantrala near the Camping-ground and along the Kortikanama path, and the subordinates and Chenchus were taught how to do the operation : the root-parasitic habit of the sandal and the species of plants in whose company sandal grows well were also explained to them.

On the 7th and 8th August, I myself supervised dibbling in of sandal with seeds of *Kanuga* and *Yegi* at Pedda-Mantala under bushes of suitable species to the north and west of the teak plantation in the cultural block. In the teak nursery, sandal and *Kanuga* were sown in a number of bamboo tubes, and the Deputy Ranger and the plantation watcher were instructed to regularly water them.

It is hoped these sowings will be better cared for and will prove much more successful than those of 1906 which was the first year in which these operations were initiated. With persistent and steady efforts at dibbling in sandal seed amidst suitable species year after year in cool localities and along streams and nullas, I think it is not too much to hope that sandal-wood would become established and spread almost throughout the Nallamalais at a comparatively small cost and within a decade or two. What is wanted is genuine interest and enthusiasm among Range officers for this work and frequent inspections and guidance by their superior officers. If we succeed in establishing even a few trees scattered over the whole Nallamalai Range, the species will spread by reason of its early sexual maturity and consequent abundant and frequent seeding, and by its prolific production of root-shoots or root-suckers.

19. Comparative merits of sandal regeneration (1) by planting out nursery-raised seedlings and (2) by sowing in-situ.

Although the experiments described in the foregoing pages were not conducted in that systematic, methodical and regular manner which would entitle their results to claim full scientific weight owing to the want of a sufficient staff—the existing staff having been fully engaged in a multitude of other important works, still the facts gathered from

them appear to me to be sufficient to indicate briefly which of the two methods of propagating sandal-wood should be adopted. From the knowledge derived from these experiments, I feel no doubt in my mind that the method of *in-situ* sowing is better than planting out nursery-raised seedlings, because, firstly, it is very much cheaper than the latter; secondly, freedom from damage to the roots and root-attachments of the seedlings and their nursery hosts—a very important point on which the success of the whole undertaking would depend; in the case of nursery seedlings, damage to roots cannot be avoided even with the best of skilled labour, which is hardly available; thirdly, the ease and quickness with which the sowing of seeds of sandal and its hosts can be performed even by the most ignorant and unskilled labourers; fourthly, the great advantage the seedlings will have of starting their life on the very spot where they are to spend their existence without change of soil and of their early associates (hosts) ; and fifthly, on account of superior and trained supervision not being necessary especially during transplantation—by no means a small consideration in these days of an inadequate Controlling staff everywhere in the Department. I lay some stress on this point because I have found by experience that even ordinary Rangers do not exercise sufficient care in lifting sandal seedlings from the nursery and in planting them out.

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PLATE I.

Figs. 1 and 2.—Two germinating Sandal Seedlings showing root-development.

Fig. 3.—A fully germinated and developed seedling with secondary root ramifications.

For full description see pages 146 and 147.

PLATE I.

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PLATE II.

FIGS. 1, 2 AND 3.—Germinating Sandal Seedlings showing emergence of plumule out of seed cover while Cotyledonary leaves are still enclosed in it.

For full description see page 147.

PLATE II.

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PLATE III.

Sandal Seedlings grown pure (unmixed with other species), illustrating the scanty root development, and stunted and unhealthy growth of leaves resulting in the early decay and death of the seedlings.

For explanation see page 147.

PLATE III.

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PLATE IV.

Sandal Seedlings with abundant roots and root-lets developed probably as a result of their association with weeds.

A, C Sandal Seedlings.

B a weed.

For explanation see page 147.

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PLATE V.

A, B, C — Sandal Seedlings.
D, E — Kanuga Seedlings.
For full explanation see page 148.

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PLATE VI.

A, B Sandal and C, D Dirasanam (Albizzia Lebbek) seedlings with root-connections. For explanation see page 148.

PLATE VI.

Engraved and Printed by The Calcutta Phototype Co.

PLATE VII.

A Sandal Seedling.
B, C Odesa (Cleistanthus collinus) seedlings.
For explanation see page 148.

PLATE VII.

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PLATE VIII.

A, B Sandal and C, D teak seedlings grown together in tile pots.
For explanation see page 148.

PLATE VIII.

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by The Calcutta Phototype Co.

PLATE IX.

Two Sandal Seedlings with mutual root-connections.
For explanation see page 149.

PLATE IX.

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PLATE X.

Diagram showing tile-cylinders arranged honey-combwise.
For explanation *see* page 149.

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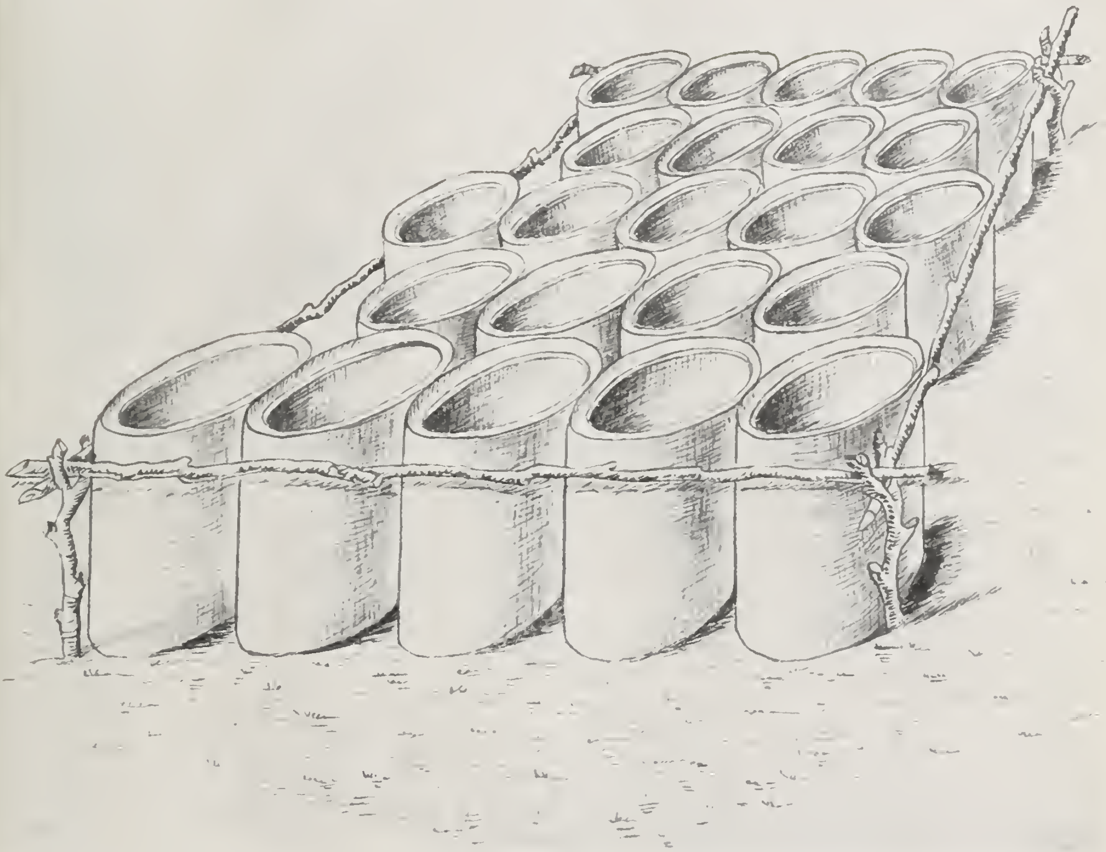

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VOL. II PART IV

THE INDIAN FOREST RECORDS

Host Plants of the Sandal Tree

BY

M. RAMA RAO
Conservator of Forests, Travancore

Published by Order of the Government of India

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
Published in October 1911

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The Host Plants of the Sandal Tree.

By RAMA RAO
Conservator of Forests, Travancore

THE great economic and commercial value of Sandalwood (*Santalum album*), its restricted occurrence over a limited area in India, its practical absence in other parts of the world, and the threatened extinction of the existing sandal by the occurrence of the "Spike" disease, point to the necessity for the adoption of earnest and vigorous measures, not only for the preservation and protection of all existing sandal growth, but also for extending its area by artificial reproduction and by effectively aiding its natural regeneration. Much appears to have been done in the past in this direction by way of plantings and sowings both in Mysore and Coorg where it occurs most abundantly, but those efforts have not been quite successful. This failure appears to be due to the ignorance of the life-history and habits of the plant and to its being treated like other species of trees in the methods adopted for its propagation. Although its root-parasitic habit was discovered 40 years ago, no value or importance was attached to the effects and influence of this peculiar habit of this species on its growth and development. It is only during recent years that the importance that its root-parasitic habit plays in its growth has been studied and it has been realised that all operations undertaken towards its regeneration must be regulated and guided by this habit of the plant. It has now been sufficiently well demonstrated that sandal derives its root-nourishment from the roots of other species of plants and that it shows a decided preference for some species more than for others. It is

therefore of the utmost practical importance to Foresters and others who deal with the protection and propagation of sandalwood to carefully investigate and ascertain which species of plants it likes best and which of them help to produce the largest quantity and the best quality of scented wood.

2. I have attempted to study this question for some time past by my own observations and from those of others who have devoted attention to this subject. The results of that study are embodied in the following pages. They are by no means exhaustive or conclusive and require to be tested and verified by further investigation and observation by others who are interested in the subject, and that is the object of the publication of these notes in spite of their admitted incompleteness.

3 The investigations made during recent years into the natural history of sandalwood by Dr. Barber, M.A., Sc.D., F.L.S., and the writer's study of its root system in the Salem, Kurnool and Bangalore Districts and elsewhere, and the observations recorded by some Forest Officers such as the late Mr. Ricketts of the Mysore service, Mr. P. M. Lushington and a few others have confirmed and established beyond all doubt the correctness of Mr. Scott's discovery in 1871 that the sandal plant is a root-parasite. Dr. Barber's and my own studies further indicate that this species depends *entirely* for its root-nourishment upon other species of plants in its neighbourhood without which it cannot live or grow. This latter statement does not appear to have been made hitherto in an authoritative and unqualified manner, but it seems to be justified by the evidence collected from Dr. Barber's pot-culture of sandal seedlings, from a series of experiments made by me in the Kurnool District in 1906 and 1907, and from other recorded observations. The available evidence is briefly set forth below:—

(*i*) *Inability of pure-grown sandal seedlings to grow and develop after the reserve materials stored in the seed and subsequently transferred to the hypocotyl are exhausted.*

This was found to be the case in *four* separate experiments made by me at Kurnool and Diguvametta by raising seedlings in nursery beds, pot-tiles, bamboo tubes and dealwood boxes. In all the experiments, the seedlings, unassociated with other species, died

out when they were about a year old while those grown with host plants continued to grow vigorously, producing lateral branches.[1] This is practically in accord with the results of Dr. Barber's experiments on the growth of sandal seedlings.[2]

The failures of early sandal plantings and sowings in the open in Mysore and Coorg, referred to in Mr. P. M. Lushington's "Notes on the Sandal Tree in Southern India," were probably due to this cause, as also the failure of sowings of sandal seed after ploughing in open glades in Mysore, and at Hassanur in the Coimbatore District, referred to in the same notes. These failures were attributed to want of shade, as the real effect of the root-parasitic habit of sandal was not so well understood then. But in the light of the results of subsequent investigations, there is little doubt that it was owing largely to the want of host-plants to derive its nourishment from, that the sandal failed in those plantings and sowings.

(*ii*) *The practical absence or, at any rate, the rarity and extreme delicacy of the root-hairs even on very young rootlets of sandal seedlings.*[2]

Dr. Barber has found some root-hairs on rootlets and haustoria, but they were comparatively small in number and minute in their size. In my examination of the root-system of numerous seedlings with a strong lens or object glass of a microscope, I could discover few or no root-hairs except on haustoria formed on the roots of *Fourcroya gigantea* on which the root-hairs were numerous and exactly like those formed on the roots of the host itself.

(*iii*) *The very early attachments of their roots and rootlets to those of other species even when the sandal seedlings are less than two months old.*

This fact has been observed by several writers; I found it in both natural-grown[3] and nursery-raised seedlings.[1]

Dr. Barber found it in his pot-grown plants.[4]

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[1] My "Notes on Sandal."—Indian Forest Records, Volume II, Part III.

[2] Dr. Barber's "Studies in Root-parasitism. The Haustorium of Santalum album," Volume I, No. 1, last sub-paragraph of paragraph 5.—Memoirs of the Department of Agriculture in India.

[3] Root-parasitism of the sandal tree.—Indian Forester, Volume XXIX, page 386.

[4] Dr. Barber's "The Study of Sandal Seedlings."—Indian Forester, Volume XXX, page 547.

(iv) Retardation and arrest of growth of sandal trees when their associates of other species are cut out.

When Mr. Scott, the first discoverer of the root-parasitism of the sandalwood, cut out trees of two species of *Heptapleurum* growing in the vicinity of two sandal trees—apparently in two different spots in the Calcutta garden—he found the sandal trees became nearly destitute of leaves and were in altogether an unhealthy and withering state. Subsequently, when the felled *Heptapleurum* produced stool shoots, the sandal trees began to revive and grow vigorously.[1]

In the Bylur Sandal Plantations of the Coimbatore District, which were started in 1870, "weeding and pruning continued up to 1889, in which year the thorny bushes were removed and burnt." In 1891, the late Mr. Rhodes Morgan recorded his opinion "that the sandalwood was a root-parasite and that the plantations were excellent up to 1880" when the plantations were "cleaned" and "pruned" after which, owing to this injudicious operation, the plantations began to go back.[2]

(v) Absence of pure-grown sandal trees (isolated or in groups) in nature.

In all the sandal tracts of the Salem and Kurnool Districts, and round about Bangalore, I have not come across a single sandal tree growing by itself without other species whose roots were beyond the reach of its own. Whenever such trees are met with, evidences of other species having existed there but since removed are invariably found, and besides, they are generally stunted and sickly, with their leaves small and yellow and their crowns unhealthy. No writer on the subject has ever brought to notice the existence of sandal plants growing as a pure crop in nature, but on the other hand, all writers are agreed that they always occur in the company of other species.

To the above may, perhaps, be added the evidence afforded by an experiment made by me at Diguvametta in planting out pure-grown sandal seedlings about six months old amidst bushes of other species. A large number so planted died out gradually, even

[1] Sir Dietrich Brandis on "Treatment of the Sandal Tree" in Indian Forester, Volume XXIX, page 3.

[2] Mr. P. M. Lushington's "Notes on the Sandal Tree in Southern India."

though regularly watered, after showing signs of recovery for several months. Two of the seedlings lingered on for seven months after transplantation and then died. Whereas among seedlings raised with host-plants in tile-pots and transplanted with the latter, a large percentage established themselves and were growing vigorously[1] when last seen by me.

It may be here noted as an additional proof of this statement that all attempts in Mysore and Coorg to raise sandal plantations by planting out seedlings, especially in the open, failed.[2]

4. These items of evidence are, I believe, sufficient to support the statement that *sandalwood cannot grow without the association of other species.* Perhaps this evidence may not be deemed conclusive enough for a scientific affirmation of the fact, but for all practical purposes it is, I think, sufficient to justify the acceptance of the statement as a settled fact.

The complete dependence of the sandal tree on the roots of its hosts for its nourishment having been established, the next questions to be settled are (1) *whether it preys upon all species alike and derives its nutriment equally from all of them or whether it exercises any selective power and chooses any particular species for its hosts,* and in the latter event (2) *what are the species it likes most.*

5. As regards the first question, from investigations in the field by digging up roots of different species associated with the sandal in its natural habitat as well as outside where it has been introduced, it has been found to attack roots of almost all species it comes into contact with, but in a very varying degree, traces of its attack being very scarce in some species, such as the custard apple (*Anona squamosa*), *Carallia lucida*, etc., while they are numerous in some others such as *Pongamia glabra*, *Albizzia odoratissima*, *Lantana Camara*, *Vitex Negundo*, etc. It has been also found that a species is largely attacked in one locality where the choice of the sandal is limited to a few species, while the same species is sparingly attacked in another locality where there is an unlimited choice of other plants. Thus, for instance, in a private compound at Cumbum in the Kurnool District and in a forest tope near Hosur in the Salem District, where the number of host-plants is limited, sandal grows luxuriantly in the company of *Cassia siamea*, largely attacking the

[1] My "Notes on Sandal."—Indian Forest Records, Volume II, Part III.
[2] Mr. P. M. Lushington's "Notes on the Sandal Tree in Southern India."

roots of the latter, whereas in certain dry localities near Bangalore, such as portions of the Peniyam Reserve, the sandal is stunted and sickly in the company of the same *Cassia.* A similar thing has been observed in the case of some other species such as *Acacia leucophlœa* and *Albizzia amara.* The extent to which a species is attacked by sandal seems to be influenced, apart from the suitability of that species as a host, by a number of other factors such as the physical condition of the soil and its drainage, on which the development and ramification of the root-systems of the host and the guest depend to a considerable degree, on the toughness or softness and the dryness or sappines of the living bark of the host, and so on. I have generally found that roots with thick and sappy barks such as those of the numerous genera of Leguminosæ are more largely attacked than those with dry and tough barks like the roots of *Elæodendron Roxburghii, Anona squamosa, etc.* Without a thorough and exhaustive examination of the roots of all species of plants indigenous in the habitat of sandalwood and which are attacked by it—a work too stupendous for any Forest Officer to undertake in addition to his multifarious other duties—it is impossible to give an exact and precise account of the degree or extent to which sandal preys upon other species of plants. But so far as my investigations into the root-systems of some of its host-plants and of its growth in their company have gone, they indicate a strong tendency in the sandal to select certain species of plants in preference to others. On examining the root-system of a sandalwood tree at Quilon growing on sandy soil in the company of *Carallia lucida, Cashew, Grewia Microcos, Lantana* and Karalankodi (*Heterostemma*), I found root-attachments of sandal with *Lantana, Karalankodi* and *Cashew,* but few or no attachments with the *Corallia* and *Grewia Microcos,* although their roots and those of the sandal crossed each other frequently. This fact has been corroborated by the results of the nursery experiments made in Diguvametta and Kurnool, where sandal seedlings were raised with different kinds of hosts, and it was found that with some hosts like the *Pongamia glabra* and *Gossypium arboreum* the sandal formed numerous attachments and grew very vigorously, while with other hosts like the plantain its root-attachments were fewer and its growth was much slower and less vigorous.[1] Dr. Barber's studies

[1] My "Notes on Sandal."—Indian Forest Records, Volume II, Part III.

of the haustoria of sandalwood on the roots of numerous species of host-plants appear to have led him to a similar conclusion.[1] We may then take it, for the purposes of practical sylviculture, as a settled fact *that sandalwood shows a decided selective power in choosing its hosts, and that it derives its nourishment more abundantly from certain species than from others.*

6. This leads us to the next question—*what are the species that form the best hosts of Sandalwood?* To answer this question fully and satisfactorily, an exhaustive study of the root-systems of all the species of plants indigenous in all the sandal areas of India and of their influence on the growth of this tree appears necessary. Moreover, a careful examination under the microscope of the sandal haustoria on the roots of its numerous associates may also be found necessary for ascertaining to what extent the haustoria successfully penetrate the woody portions of the hosts, as, without such penetration, sandal appears to derive little or no nourishment from them, even though it forms root-connections. The results of Dr. Barber's investigation under the microscope have been published in the Memoirs of the Department of Agriculture in India in two parts under the title "Studies in Root-parasitism. The Haustorium of Santalum album."

7. This most valuable and useful work does not deal with the haustoria formed on all the species associated with the sandal as Dr. Barber examined them only on 89 species, while the number of associates exceeds 250—including exotics with which sandal wood is found to grow in gardens. Microscopical examination of the haustoria on some of the associates may be dispensed with, as the best practical test of successful penetration is afforded by the scars visible to the naked eye, of fallen-off haustoria on the woody portions of the roots attacked. In some cases, such scars are covered over by the formation of *callus* or new growth from the cambium, leaving only a superficial trace of sandal attack, for example, roots of *Albizzia odoratissima* and *Pongamia glabra*, but in such cases a cut with a knife may disclose the depth to which the haustorium had penetrated. Again, in some cases, such as the green aloe (*Fourcroya gigantea*), no penetration into the woody central cylinder may be discovered under the microscope, the progress of the haustoria

[1] "The haustoria of Sandal roots" by Dr. Barber.—Indian Forester, Volume XXXI, page 190.

being arrested by the thick ring of sclerotic tissue, which protects the internal woody cylinder. But, still, sandal may thrive well in hedges or clumps of that species, of which a number of instances are found in Bangalore and its suburbs. How in such cases the sandal derives its nutriment is a puzzle unless it be that its requirements are supplied by the living bark and by the soft and unlignified fibro-vascular bundles of tender rootlets, of which I could find no proof in the haustoria examined by me under the microscope. To add to all these complications, there is the most difficult task of finding a sandal tree growing only with one of its numerous hosts at a time, unaided by others in its growth. We invariably find in nature a sandal tree growing with a number of hosts all or most of which may contribute their share towards its growth, thus rendering the determination of the exact amount of influence exerted by each tree or species on the development of sandal a difficult, if not an impossible, problem. Two ways suggest themselves to me as likely to yield a practical solution of this difficult question and these are (1) the artificial cultivation of the sandal tree in the company of each of its hosts separately, precluding all possibility of its coming in contact with other species of plants throughout its growth, and (2) isolation of existing young sandal plants *in nature* from all other kinds of plants than the one whose influence is proposed to be determined, by destroying those with root and all, and keeping them (sandal plants) so isolated till they attain to their exploitable age. In both cases a number of experiments must be made in respect of each species of host so as to arrive at final and reliable conclusions. Both the ways are tedious, laborious and expensive, though the second is less so than the first, and require patient waiting for a long number of years—at least 40 in my opinion. Such experiments will not only help to determine the best hosts of the sandal, but may also throw light on the question whether and to what extent they exert any influence on the development of scent. If the data aimed at are worth having, which very few who know the great value of sandal would deny, all the time, trouble and money required for the conduct of the experiments would be as nothing to the results which could be achieved. When experiments in connection with agricultural crops require several decades and several thousands of pounds of money, such as those conducted by Sir John Gilbert and Lawes at Rothamstead, what

wonder that experiments on forest crops which take several generations to mature should demand great patience and ample funds!

8. From the foregoing remarks it will be readily understood that such information as a Forest Officer can collect on the subject from his own observations in the field, in addition to his other executive duties, can neither be thorough and complete nor quite accurate and conclusive. From the nature of the subject itself, the limited area of the natural sandal tracts which came under my observation, the restricted opportunities for study of the sandal and its hosts owing to the inaccessible situation of the localities where it occurs in the Salem and Kurnool Districts, far away from the main centres of heavy forest works where most of my time was spent, the following notes collected under the above disabilities cannot but be imperfect, inconclusive and perhaps inaccurate in some instances. In venturing to publish them in this defective and imperfect state, my sole object is to appeal by this means to Forest Officers and others who have had and still have opportunities of studying the subject, to publish the results of their studies and observations so that in the course of a few years sufficient materials may be collected for compiling a correct life-history of the sandal tree and of the relative influence of its various hosts on its growth and development. The Mysore State being the home of the sandal tree, which yields an average annual outturn of 2,000 tons of cleaned wood valued at Rs. 12,00,000, I would specially appeal to the Mysore Forest Officers to publish their observations already recorded if any, to carry out further observation and study, and to publish results periodically. To those officers who cannot command the requisite time and patience to examine the root-systems of the various hosts of sandal in its neighbourhood, I would suggest the much easier and quicker mode of collecting information by going along the beds of rivers, streams and nallahs on whose banks sandal trees occur and noting carefully the occurrence of sandal haustoria or their scars or both on the roots of the host-plants, exposed to view on the slopes of the banks. Where doubts arise as to whether an affected root is of a given species existing there or whether the haustoria are those of sandal or of any other root-parasite, such as those of the *Olacaceæ*, it would be an easy matter to trace either of them to its source by a little digging. By this mode I have collected a good deal of information in the course of a single morning's ramble which would

have taken several days or weeks to collect, had the other alternative of digging up roots of host-plants on plains or hill slopes been adopted.

9. In the description of the haustoria or their scars and the extent of attack on each species of hosts examined or observed by me, numerous repetitions occur; but I consider it better to retain them rather than aim at brevity at the expense of details which may eventually help us in arriving at generalisations regarding the influence exerted by a genus or a sub-family or a family as a whole on sandalwood. The accompanying plates of some of the roots attacked showing the haustoria and their scars were prepared at the commencement of my investigations, but no drawings of roots subsequently examined were prepared as it was thought unnecessary and expensive to do so.

10. The following is a brief account of the host-plants observed and examined by myself and by others:—

I. Dicotyledons.

Anonaceæ.

(*1*) *Goniothalamus wynaadensis*—(Evergreen shrub) Javadi Malayalees call it *Pulichan sedi.*—The roots of this plant are pretty largely attacked by sandal roots whose haustoria penetrate to the woody cylinder. The haustoria are of medium size and pretty deep, but not high above the host's surface. This shrub is not common in the sandal tracts, but is occasionally met with associated with sandal in Kambugudi and elsewhere on the Javadi hills.

(*2*) *Goniothalamus sp.*—(Evergreen shrub) Javadi Malayalees call it *Kakanan sedi.*—This is also attacked by sandal roots more or less like No. 1.

(*3*) *Anona squamosa*—(Semi-evergreen small tree).—Only one root examined; bore superficial scars of sandal haustoria which had penetrated to the woody cylinder of the host; does not seem to be affected to the same extent as No. 1 and probably less hospitable; the scars seemed to have been healed by *callus* growth from the cambium in the specimen examined.

(*4*) *Polyalthia longifolia*—(Evergreen tree).— } Attacked
(*5*) *Artabotrys odoratissimus*—(Evergreen climber).— } roots of

these two species have not been examined by me, but Dr. Barber[1] has examined the sandal haustoria formed on them; how far these species are attacked by the sandal and whether they serve as good associates require further investigation.

MENISPERMACEÆ.

(*6*) *Tinospora cordifolia*—(Deciduous climber).—The roots of a small plant were found attacked and two living haustoria and four scars of withered ones were found; the haustoria were of moderate size and had penetrated the woody cylinder. This species appears to be a moderately good nurse to sandalwood in its early stage of growth.

CAPPARIDEÆ.

(*7*) *Capparis zeylanica*—(Deciduous shrub).—I examined a few roots and found living sandal haustoria and scars of withered ones on them. The haustoria were of medium size, broad and flat-based and pretty high above the surface of the host. Examination under the microscope showed penetration with sucker lobes surrounding the woody cylinder of the host over more than half the length of its circumference; this species appears to be pretty largely affected and may be a good nurse in dry localities where it is commonly found.

MALVACEÆ.

(*8*) *Thespesia populnea*—(Evergreen tree).—The roots and rootlets of this plant are very largely attacked and the haustoria are somewhat larger than those found on the species already described above. The roots being full of warts, not infrequently the haustoria are formed on them; microscopic examination shows complete penetration, the sucker-lobe extending sometimes to the centre of the woody cylinder; the scars are deep and expose the wood of the host to view.

This species seems to form an excellent nurse for sandal, though an exotic to the natural habitat of sandal; it reproduces itself readily from cuttings, thus rendering its propagation easy and

[1] Dr. Barber's "Studies in Root-parasitism—The Haustorium of Santalum album," Volume I, No. 1, Part 2.—Memoirs of the Department of Agriculture in India.

produces a large net-work of side roots and rootlets all of which are attacked. It yields good timber. Plate I is a half-size drawing of one of the roots examined by me.

(*9*) *Sida carpinifolia*—(Evergreen undershrub).—I found roots of this attacked but only occasionally, as only one haustorium and a couple of scars were found on the whole root-system of a plant. It may not be a good nurse.

(*10*) *Sida rhombifolia*—(Evergreen undershrub).—The sandal haustoria on the roots of this plant were examined by Dr. Barber who found them penetrating the woody cylinder.[1]

(*11*) *Gossypium arboreum*—(Deciduous small tree).—Numerous root-attachments between this species and sandalwood were found and a sandal seedling in its company was growing remarkably well, while other sandal seedlings, far away from it and without any root-attachments, were stunted and poorly in appearance.[2] In the early stages of growth of the sandalwood the cotton plant appears to be a very good nurse for it; as it also yields cotton, its introduction as a nurse may be doubly advantageous.

Sterculiaceæ.

(*12*) *Sterculia alata*—(Deciduous tree).—
(*13*) *Pterospermum suberifolium*—(Evergreen tree).—
(*14*) *Pterospermum Heyneanum*—(Evergreen tree).—
(*15*) *Guazuma tomentosa*—(Deciduous tree).—

Attacked roots of these species were not examined by me, but Dr. Barber has examined sandal haustoria on them all[1] and found penetration into their woody cylinders. Their practical utility as nurses to sandal plants has to be determined by further investigation in the field.

Tiliaceæ.

(*16*) *Berrya Ammonilla*—(Evergreen tree).—I have not seen attacked roots of this plant. Dr. Barber refers to the sandal haus-

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[1] Dr. Barber's "Studies in Root-parasitism—The Haustorium of Santalum album," Volume I, No. 1, Part 2.—Memoirs of the Department of Agriculture in India.

[2] My "Notes on Sandal."—Indian Forest Records, Volume II, Part III.

toria on them. Affected roots of this species have to be examined to ascertain to what extent it may prove useful as a nurse.

(17) Grewia sp. (Tamil—*Pannipudukan*)—Deciduous shrub.—Its roots are largely attacked, numerous scars and haustoria being found on the main as well as the side roots and rootlets; the haustoria are medium sized and whitish-brown when dry, with a thin and broad base closely adhering to the surface of the host and the central portion flattened on two sides along the axis of the host; the scars are deep and expose the host's wood to view; the haustoria are not lignified. This Grewia appears to love moist and deep soils and to be a good nurse for the sandal in such localities; its wood is pretty hard and useful for small timber.

(18) Grewia hirsuta—(Deciduous shrub).— } Attacked roots of
(19) Gerwia tiliæfolia—(Deciduous tree).— } these plants were not examined by me, but Dr. Barber examined sandal haustoria on their roots and appears to have found them successfully penetrating to the woody cylinder of the hosts. Perhaps they are as good nurses as *Pannipudukan* and yield better timber; affected roots of both species have to be examined in the field to ascertain their value as nurse plants for sandalwood.

Geraniaceæ.

(20) Averrhoa Carambola—(Deciduous tree).—Roots of this tree were found affected by sandal roots in a garden near the Lalbagh at Bangalore and bore living haustoria of a whitish-brown colour and of medium size; they penetrate the woody cylinder of the host as seen in the scars on the hosts; the sandal seems to prey on this species only to a moderate extent; being a fruit tree its association with sandal might be found doubly profitable.

Rutaceæ.

(21) Limonia acidissima—(Semi-evergreen tree).—This is very extensively attacked and the sandal haustoria on one of the roots examined were pretty large, being more than $\frac{1}{2}$ inch long and $\frac{3}{8}$ inch broad with a flat base closely adhering to the surface of the host and the central portion raised; the haustoria had penetrated to the woody cylinder as seen by the exposed wood in the scars of withered ones on the host. This appears to be a good nurse and yields fairly

good small timber; it occurs in dry sandal tracts somewhat sparsely and deserves to be encouraged as an associate of sandal. One of the roots examined by me is illustrated in plate VI, opposite page 389 of the Indian Forester, Volume XXIX.

(22) *Citrus Aurantium*—(Semi-evergreen).—I found roots of this species pretty largely attacked in a garden at Salem; the roots examined were small and contained numerous haustoria and scars; the haustoria were of medium size and woody and had penetrated the xylem of the host as the scars showed it clearly. Though not indigenous in the habitat of sandal, this seems to be a good host and it would be doubly profitable to grow it with sandal on account of its fruit and small timber also. In some cases the wounds made by the haustoria had been covered over by *callus* wood.

(23) *Toddalia aculeata*—(Evergreen climbing shrub).—
(24) *Clausena indica*—(Evergreen shrub).—
} I have not seen roots of these two species: Dr. Barber examined sandal haustoria on them and found them penetrating the woody cylinder. As they are commonly found in dry sandal tracts, they are probably good hosts. How far they influence the growth of sandal must be ascertained by examining their roots in the proximity of sandal plants.

SIMARUBEÆ.

(25) *Ailanthus excelsa*—(Deciduous tree).—The soft wooded roots of this species are pretty largely attacked; on young roots I found the scars of haustoria to be oval and deep, while on older roots they were circular and shallow, owing probably to the formation of *callus* wood; in the specimens preserved by me no haustoria are found, though I remember to have collected some living haustoria and sent them to Dr. Barber. This is not a common associate of sandal, being only occasionally met with in sandal areas.

BURSERACEÆ.

(26) *Protium caudatum*—(Deciduous tree).—This plant is affected to a moderate extent and sandal haustoria are of medium size and whitish-brown in colour; they penetrate into the woody cylinder of the host as shown by the scars of withered haustoria; though not a timber tree, it occurs commonly in the natural sandal tracts in Mysore, Salem and Kurnool Districts. I have seen sandal

trees in its neighbourhood fairly healthy and vigorous in growth and it appears to be a tolerably good nurse.

MELIACEÆ.

(27) *Melia Azadirachta*—(Deciduous tree).—The affected roots of this tree examined by me were rather sparsely attacked by sandal roots and the haustoria were of moderate size; the haustoria appear to penetrate to the woody tissues of this host as ascertained by Dr. Barber's investigations under the microscope. A sandal tree growing within reach of a *nim* tree without any other host close by in Mr. Foulkes' compound at Salem had yellow coloured wood and was fairly vigorous in growth. I have elsewhere seen sandal growing vigorously in the company of this species. As it also yields moderately good timber, its cultivation with sandalwood is desirable.

(28) *Cipadessa fruiticosa*—(Evergreen shrub).—The roots of this plant are also attacked pretty largely; a number of medium-sized haustoria and scars were found in the specimens examined and the latter were deep and exposed to view the woody cylinder of the host; in some of the sandal tracts in India it is commonly found and appears to be a good nurse for young sandal.

OLACACEÆ (*Olacineæ*).

(29) *Cansjera Rheedii*—(Evergreen climber).—I have not examined the roots of this climbing plant in the neighbourhood of sandalwood, but Dr. Barber examined sandal haustoria on its roots under the microscope and found penetration of the haustoria into the woody cylinder. The extent to which this plant and others of the *Olacaceæ* commonly found in sandal areas, such as *Ximenia americana*, *Olax scandens*, *Opilia amentacea*, all of which are themselves root-parasites, are affected by the sandal, requires further investigation in the field.

CELASTRACEÆ.

(30) *Elæodendron Roxburghii*—(Evergreen tree).—I examined only one root of this species close to a sandal tree and found some small haustoria on it; they were flat, small and ineffective, as no penetration even into the living bark was found in the scars of some

haustoria which appeared to have prematurely withered away. Plate II is an illustration of the root examined. It is doubtful whether this plant is a good nurse for sandal; further investigation of its affected roots is necessary.

(*31*) *Celastrus paniculata*—(Semi-evergreen climber).— } Although
(*32*) *Gymnosporia montana*—(Deciduous shrub).— } I have not
examined affected roots of these plants, Dr. Barber seems to have examined sandal haustoria on them under the microscope. These species are not uncommon in sandal areas in the Salem and Kurnool Districts. How far they are helpful to the growth of sandalwood requires further investigation.

RHAMNEÆ.

(*33*) *Zizyphus Œnoplia*—(Semi-evergreen climber).—I found the roots of this very largely attacked and the scars of the haustoria were of medium size and deep, showing the woody portion of the host; the few haustoria seen on the roots were whitish-brown in colour and not well-lignified. This is a most common associate of sandalwood in its natural habitat, especially in dry scrub jungles, and appears to be a very good nurse, judging from the vigorous growth of the sandal plants in its neighbourhood.

(*34*) *Ventilago madraspatana*—(Deciduous climber).—Two long roots of this species were examined and only one haustorium on each was found; it was small and ill-developed in both cases and penetration into the woody cylinder had not been effected. It does not appear to be of much use to the sandal as a nurse.

(*35*) *Zizyphus rugosa*—(Deciduous climber).—Dr. Barber has examined sandal haustoria on this root. I have not seen affected roots of this plant: its utility as a host plant requires further investigation.

SAPINDACEÆ.

(*36*) *Schleichera trijuga*—(Semi-evergreen tree).—A root of this plant was found to have been affected moderately, but the root collected having been lost, it is not possible for me to describe the extent of the attack and the usefulness of this species as a host.

ANACARDIACEÆ.

(*37*) *Mangifera indica*—(Evergreen tree).—I found the roots of this species largely attacked by sandal roots and the scars of haustoria on them pretty large, being in some cases $\frac{1}{2}$ inch long and $\frac{3}{8}$ inch broad; in a few cases the wood of the host had been penetrated. In some places I found sandal growing vigorously near the mango, while, in others, it was sickly and yellow-leaved. Its value as a host has to be determined by further observations. From observations in various places I am led to suspect that the sandal would avoid this species if it has more congenial hosts to live upon, possibly owing to the acrid juice of this plant.

(*38*) *Anacardium occidentale*—(Semi-evergreen tree).—Mr. A. W. Lushington, Conservator of Forests, has found sandal seedlings establishing root-attachments with this species in the forest garden at Waltair. I have not met with its affected roots in the natural sandal areas I have seen, but in a garden at Quilon I found its roots attacked and a few haustoria formed on them.

LEGUMINOSÆ.

(*39*) *Clitoria sp.*—(Deciduous twiner).—A young plant of this species bore four small sandal haustoria on its roots; the haustoria were woody and hard; seemed to have penetrated to the woody cylinder of the host; in some sandal tracts this is often met with.

(*40*) *Dolichos Lablab* (*Sittāvārai* in Tamil)—(Deciduous twiner).—The succulent and tuberous tap-root and rootlets of this species were attacked by sandal in two different plants. The living haustoria on one were much larger than in the other; this plant seems to be a good host for young sandal.

(*41*) *Dalbergia Sissoo*—(Evergreen tree).—The roots of a sissoo tree were very extensively attacked by the sandal roots in the Denkanikotta Forest Office compound. The haustoria were comparatively large, hard and prominently high; the scars were deep, exposing the wood of the host to view. Though an exotic to sandal tracts, it would probably form a very good nurse wherever it could be grown with sandal. Being a timber tree its introduction into sandal areas would be doubly profitable. Plate III illustrates a root collected by me.

(*42*) *Dalbergia paniculata*—(Deciduous tree).—This species appears to be pretty largely affected; the root examined by me contained a number of scars but no living haustoria; the scars were deep and of medium size and the woody cylinder of the host was exposed to view in most of them. Though not otherwise of much use, it appears to be a fairly good nurse.

(*43*) *Dalbergia scandens*—(Evergreen climber).—Dr. Barber has examined sandal haustoria on this species and found them penetrating to the woody cylinder. But I have not seen affected roots of this climber; being pretty common in sandal areas, it may prove a good nurse.

(*44*) *Peltophorum ferrugineum*—(Evergreen tree).—Sandal haustoria on the roots of this species were examined by Dr. Barber who found them penetrating its woody tissues and breaking up and devouring the smaller roots. Its value as a nurse has to be ascertained after further investigation.

(*45*) *Pongamia glabra*—(Evergreen tree).—I have examined affected roots of this species in various places in the Salem, Kurnool and Bangalore Districts, and have found them most extensively attacked; most of the roots examined had been simply riddled with scars of haustoria and in some cases living haustoria were also found; they are very large, prominently deep and enter into the woody tissues of the host. Some of the scars were more than one inch long and half inch broad. In the neighbourhood of this species, sandal trees were found growing very vigorously, and in nursery experiments, this was found to be the best host among those experimented with. Being a comparatively quick grower and useful as a petty timber and good fuel and oil-seed yielding plant, I consider this species as one of the best nurses for sandalwood. Even on dry and high places round about Bangalore I have seen sandal trees in the company of this species growing vigorously, while trees in the company of other species were somewhat stunted and sickly. It appears to be very common in the sandal tracts of the Mysore Province.

(*46*) *Pterolobium indicum*.—(Semi-evergreen climber).—Dr. Barber has examined sandal haustoria on its roots and found them entering the woody cylinder; I have not seen its affected roots. It is a very common thorn in the sandal areas of South India.

(*47*) *Tamarindus indica*—(Evergreen tree).—Though found in

the natural habitat of sandal, it does not seem to be so largely affected as other species of the same family; in the roots examined by me there were a number of small-sized scars of withered haustoria exposing the wood of the host. I have found sandal trees growing vigorously in its company in some places, while in others they were stunted and yellow-leaved. Perhaps its dense shade and acidity of its sap do not quite suit the taste of the sandal.

(*48*) *Adenanthera pavonina*—(Deciduous tree).—Dr. Barber has examined sandal haustoria on this species and found them penetrating the woody tissues of the host and breaking them up. I have not seen its roots attacked. It is likely to be a good nurse.

(*49*) *Parkia biglandulosa*—(Deciduous tree).—Dr. Barber has examined sandal haustoria on its roots and found them penetrating the woody cylinder of the host. I have not seen its attacked roots; whether this species is a good nurse or not requires to be investigated in the field.

(*50*) *Leucæna glauca*—(Evergreen shrub or small tree).—Dr. Barber mentions this as one of the species the sandal haustoria on whose roots were examined by him. Not having seen its affected roots, I cannot say anything about its value as a host-plant. It requires further investigation.

(*51*) *Acacia pennata*—(Evergreen climber).—This is very largely attacked and young sandal trees thrive very vigorously in its company. The haustoria and scars are pretty large and the former lignified and hard; they penetrate to the woody cylinder. I have no doubt that this is an excellent nurse for sandal and is commonly found in sandal tracts.

(*52*) *Acacia Intsia* (*cæsia*)—(Semi-evergreen climber).—This is also very extensively affected, more so than *A. pennata*. The haustoria and scars are about the same size as in the latter and equally hard and penetrate to the woody cylinder of the host; a root, 22 feet long, bore haustoria and scars throughout its whole length; the haustoria were prominently high. Plate IV is the drawing of a root collected by me. This is an excellent nurse for sandal and is very common in all sandal tracts.

(*53*) *Acacia concinna*—(Semi-evergreen climber).—I have not examined its affected roots, but Dr. Barber has examined sandal haustoria on them and found them penetrate to the woody tissues of the host; it appears to be a common associate of sandal round

about Bangalore and in other parts of the Mysore Province. I have seen sandal trees growing vigorously in its company in the suburbs of Bangalore and at Butchipally near Chikkaballapur. It is also a very good host for sandal and yields the valuable *Seekai* (soap-nut).

(54) Acacia Suma—(Deciduous tree).—Round about Bangalore and in some of the Denkanikotta sandal areas I found this species associated with sandal. It is very largely attacked; the scars of haustoria in some cases were more than one inch long and $\frac{3}{4}$ inch wide and exposed the woody cylinder of the host to view; callus wood had been formed in some of the wounds caused by the haustoria; the haustoria were prominently high and woody in some cases. Though as a timber tree it is not of much use, it seems to be an excellent host for sandal. Even its thick roots are attacked largely.

(55) Albizzia Lebbek—(Deciduous tree).—This is affected to a moderate extent; the scars of haustoria are fairly large and deep, showing up the woody tissues of the host to view. Even large roots are attacked and it appears to be a tolerably good nurse. Being a useful timber tree its association with sandal deserves to be encouraged; it is common in all sandal tracts, though occurring sporadically.

(56) Albizzia odoratissima—(Semi-evergreen tree).—Sandal grows very luxuriantly when associated with this species on the Javadi hills, especially at Kambugudi and elsewhere. The scars of haustoria are very large, being sometimes an inch long and $\frac{3}{4}$ inch broad and very deep, though, in the many cases examined by me, they were covered over by callus formation. This is one of the best hosts of sandal and being also a very good timber tree, its growth with sandal enhances the value of the yield. Two affected roots of this are figured in plates IV and V published in the September number of the Indian Forester, Volume XXIX.

(57) Albizzia amara—(Deciduous tree).—I found a root 50 feet long of this species covered with sandal haustoria all along its length, but the haustoria were somewhat far apart, of medium size and hard. Some of the scars were covered over by callus wood. This tree yields good firewood and small timber and is a common associate of sandal in dry scrub jungles. It may not be as good

a nurse as the other two *Albizzias* described above, but it is a useful associate.

(*58*) *Pithecolobium dulce*—(Evergreen tree).—Sandalwood is found to grow very well when associated with this species. I found two trees supporting six sandal trees in the Denkanikotta Forest Office compound without the aid of any other species and all the six trees were vigorous and healthy. It is largely attacked, even big roots not being spared; the haustoria in the specimens examined were of medium size, hard and high, and the scars deep, exposing the inner wood of the host to view. Being a quick grower and useful as firewood, it is desirable to introduce it into sandal tracts where good indigenous nurses are wanting.

(*59*) *Pithecolobium Saman*—(Semi-evergreen tree).—I have not seen affected roots of this species, but Dr. Barber has examined sandal haustoria on them and found them penetrating to the woody cylinder of the host. It may be a good nurse for sandal, judging from the extent of its attack on allied species. Its affected roots require further examination in the field.

(*60*) *Kattu-tamatai* (Tamil)—(Deciduous climber).—This is a comparatively stout leguminous climber with pink flowers and large pods. I found its roots most largely attacked by sandal roots; the haustorial scars were large and deep, in some cases burrowing into the wood of the host; some of the scars were covered over by callus wood and the roots examined were almost completely covered with scars. This is an excellent host for sandal and grows commonly at elevations above 2,500 feet.

(*61*) *A leguminous climber*—(Deciduous).—With pink flowers resembling *Dolichos Lablab* but much stouter; was found very largely attacked and bore haustorial scars and haustoria which were quite conical, woody and high in some cases and flat and membranous in others; penetration had been effected as the scars were deep and exposed the inner wood to view. This was found at Salem 950 feet above sea-level associated with sandal in a garden hedge.

(*62*) *Cassia auriculata*—(Evergreen shrub).—This is said to be very largely attacked and Dr. Barber has examined sandal haustoria on its roots. I have not seen its affected roots. For young sandal it is considered an excellent nurse.

(*63*) *Cassia siamea*—(Semi-evergreen tree).—This is extensively attacked in some localities and sandal grows very well in its com-

pany in deep red soil, but in dry and high lands I have seen sandal growing very poorly in its company.

(*64*) *Castanospermum australe*.—Dr. Barber has found sandal haustoria on this species penetrating its roots and devouring small ones. It may prove a good host. Further examination of affected roots to see the extent of attack seems necessary.

COMBRETACEÆ.

(*65*) *Combretum ovalifolium*—(Deciduous climber).—The traces of attack on this species were not numerous in the roots examined; only a few haustoria and scars were found on a root about 2 feet long and they were of medium size and scars deep exposing the wood of the host to view; this species is commonly found in sandal areas.

(*66*) *Gyrocarpus americanus*—(Deciduous tree).—The sandal attack on this species is pretty extensive and the haustoria burrow into its soft and spongy woody tissues destroying them; the haustoria on the specimen examined were of medium size and flat. This species is occasionally met with in sandal tracts. Sir D. Brandis has included this species under *Hernandieæ*.

(*67*) *Terminalia Arjuna*—(Deciduous tree).—I examined only one root of this and found it attacked moderately; the root collected having been lost I am unable to describe the haustoria or their scars on this species. Dr. Barber has examined the haustoria under the microscope and found them penetrate into the woody tissues.

(*68*) *Terminalia Chebula*—(Deciduous tree).—I have not seen attacked roots of this species. Dr. Barber examined sandal haustoria on them under the microscope. To what extent this is useful as a nurse for sandal requires further investigation.

MYRTACEÆ.

(*69*) *Eugenia jambolana*—(Evergreen tree).—A young affected root of this tree contained a number of medium-sized haustoria and scars which were covered with a layer of dark-coloured cork; the haustoria had penetrated the woody clinder of the host; being a good timber tree, its association with sandal would be doubly profitable. Mr. G. W. Thompson found young sandal seedlings attacking rootlets of this species.[1]

[1] The "Indian Forester," page 123, Volume XXX.

(*70*) *Psidium Guayava*—(Evergreen tree).—I found young rootlets of this plant more largely affected than bigger ones; the haustoria on the former were small while on the latter they were much bigger; in both penetration had been effected, but in young roots the woody tissues had been disorganized and the haustoria burrowed into the wood right up to the pith destroying the host's tissues; in the bigger roots the cells in contact with the sucker lobes had been dissolved. This appears to be a good nurse and being a fruit tree would be profitable also on that score when associated with sandal.

(*71*) *Eucalyptus globulus*—(Deciduous tree).—I found roots of this pretty largely attacked and the sandal haustoria large on big roots and medium-sized on smaller ones; the haustoria had penetrated the inner wood; the larger haustoria were of white brown colour and flat, closely adhering to the host like limpets and were not woody or lignified. As this is a fast growing timber-yielding tree, its association with sandal would be very advantageous. Plate V is an illustration of an attacked root.

Samydaceæ.

(*72*) *Casearia tomentosa*—(Deciduous tree).—A small root of this was covered with numerous sandal haustoria and scars of medium size; the scars were deep and exposed the inner wood to view; this species appears to be an excellent host for sandal and is a desirable associate on account of its timber also.

Cucurbitaceæ.

(*73*) *Cucurbita dioica*—(Evergreen climbing herb).—I found roots of this species attacked by sandal; the haustoria were small and the only scar seen exposed the inner wood to view. This appears to be a good nurse in the younger stages of sandal plants.

Begoniaceæ.

(*74*) *Begonia* (garden)—(Evergreen herb).—Dr. Barber examined sandal haustoria on the species; not being a denizen of sandal tracts and being only an ornamental herb, it is not of importance as a host plant.

CACTEÆ.

(75) *Opuntia Dillenii*—(Evergreen bushy shrub).—Sandal affects this plant also pretty largely; the haustoria and scars were of medium size in the roots examined and had penetrated the woody cylinder. As more useful and less obnoxious nurse plants are found in sandal areas, it is undesirable to encourage this species.

ARALIACEÆ.

(76) *Heptapleurum verticillatum*—(Semi-evergreen shrub).—
(77) *Heptapleurum venulosum*—(Semi-evergreen shrub).— I have not examined the roots of these species, but Mr. Scott discovered in 1871 their root-attachment with those of the sandal; on felling these trees close to sandal trees he found the latter withering and becoming sickly, thus proving that the sandal trees depended upon them for nutriment. I have seen a sandal tree growing vigorously in the midst of a *H. venulosum* bush at Yercaud on the Shevroy Hills.

(78) *Panax* (garden)—(Evergreen shrub).—This is on Dr. Barber's list of species on whose roots sandal haustoria were found and examined by him. He found them penetrating woody tissues. But no information as to the extent of its utility as a host of sandal is forthcoming; it requires further investigation.

CORNACEÆ.

(79) *Alangium Lamarckii*—(Deciduous tree).—The haustoria and scars are of medium size and the former deep showing up the inner wood to view. This species is pretty largely affected and being common in dry localities it appears to be a desirable host for sandal. It yields also small timber.

RUBIACEÆ.

(80) *Morinda citrifolia*—(Deciduous tree).—The roots of this species are largely affected by sandal roots; some of the scars of haustoria on a root were pretty large and exposed the inner wood to view while others were covered over by callus wood. It appears to be a good nurse for sandal, judging from the large number of attacks on a single root examined by me. It yields light and good

wood useful for *sandals*, toys, etc. In its neighbourhood I have found sandal trees thriving well.

(81) *Webera asiatica*—(Evergreen shrub).—I have found young sandal plants forming root-attachments with this species. It occurs in all sandal tracts and appears to be a good nurse for young sandal.

(82) *Pavetta indica*—(Semi-evergreen shrub).—Dr. Barber has examined sandal haustoria on its roots. I have not seen its affected roots. It is pretty common in sandal tracts in the Kurnool and Salem Districts.

MYRSINEÆ.

(83) *Ardisia humilis*—(Deciduous shrub).—Javadi Malayalees call it *Maniputtan*. This is moderately attacked by sandal roots. The scars on the roots collected by me are a little above medium size and deep enough to expose the woody cylinder to view. Some of the scars were covered up by callus wood. This species is found associated with sandal only on the hills above 2,500 feet in the Salem District.

SAPOTACEÆ.

(84) *Mimusops Elengi*—(Evergreen tree).—The roots of this tree were found largely attacked in the neighbourhood of sandal trees on the Javadies; the haustorial scars were numerous, pretty large and deep and the inner wood of the host was visible through them; in some the wound was covered over by callus formation. Wherever it could be induced to grow in sandal areas, it is desirable to encourage it as a nurse, as it also yields pretty good timber and sweet-scented flowers.

EBENACEÆ.

(85) *Diospyros Kanjilali*—(Semi-evergreen tree).—This is also largely attacked, the roots examined by me close to a sandal tree being full of scars of the sandal haustoria with only a few living haustoria on them. The haustoria Dr. Barber examined under "*Diospyros montana*" were really found on the roots of *D. Kanjilali*, but when they were sent to him from Salem it had not been treated as a separate and distinct species. The Malayalees of

Kambugudi on the Javadies call it *Nochikonnai*. I found sandal trees growing well in its vicinity at that place and I consider it to be a tolerably good nurse. It is found above 2,500 feet on the hills of the Salem District.

Oleaceæ.

(*86*) *Jasminum malabaricum*—(Deciduous shrub).—
(*87*) *Jasminum rigidum*—(Deciduous shrub).— Dr. Barber has examined sandal haustoria on the roots of both these species and found those on the latter (*J. rigidum*) species penetrating to the woody cylinder: but in regard to the other he does not mention whether he found penetration or not. I have not seen affected roots of either. Being small shrubs they may be of some service to sandal plants in their early stages. Their affected roots require further examination to find out how far they are useful as nurses.

(*88*) *Linociera malabarica*—(Evergreen tree).—I have found roots of this affected but only to a small extent; though found at elevations above 2,500 feet in sandal areas it is not very common. The scars on the piece of wood collected by me are pretty large and show up the inner wood to view.

(*89*) *Olea dioica*—(Semi-evergreen tree).—This is called in Tamil *Kanai-Porumbulu* by the Malayalees on the Javadies and in Telugu *Sela-Kungudu* by Chenchus on the Nallamalais of the Kurnool District. The roots are affected by sandal, but the root collected having been lost, further investigation is necessitated.

Salvadoraceæ.

(*90*) *Azima tetracantha*—(Almost evergreen shrub).—In the roots examined the sandal haustoria and scars were comparatively small and rather far apart; the scars were deep and exposed the inner wood to view. Being a comparatively small and thorny shrub, it may be of use to young sandal to a small extent.

Apocynaceæ.

(*91*) *Carissa Carandas*—(Almost evergreen shrub).—A dead root of this species found close to a sandal tree contained a number of

haustorial scars and one living haustorium which was a little larger than of medium size. The scars showed penetration of the haustoria into the woody cylinder. This seems to be a good nurse for sandal and is commonly associated with it, especially in dry scrub jungles.

(*92*) *Wrightia tinctoria*—(Deciduous tree).—The tap-root and side-roots of a small tree were covered with a large number of haustorial scars and only two living haustoria; a few of the scars were large and showed up the inner wood of the host to view; this species seems to be very extensively attacked and must therefore be a very good host. Being common in dry scrub forests, it will be a useful nurse for sandal.

ASCLEPIADACEÆ.

(*93*) *Dregea volubilis*—(Deciduous climber).—The roots of this plant are very extensively attacked. As the roots are thick-barked and soft wooded, the sandal haustoria penetrate to the wood and disorganise the tissues of the host; the haustoria are very large and woody and the scars large and deep. Being a stout climber, it appears to be a very good nurse for sandal although otherwise of little economic value.

(*94*) *Heterostemma* sp. (Karalankodi, Tam.)—(Deciduous).—An Asclepiadaceous plant resembling *Hemidesmus*. This is moderately attacked and the haustoria and scars are of medium size; they penetrate to the wood. It occurs commonly in sandal areas.

(*95*) *Sarcostemma brevistigma*—(Evergreen climber).—I have not seen attacked roots of this plant, but Dr. Barber has examined sandal haustoria on its roots. Its attacked roots require further examination to ascertain to what extent it serves as a nurse for sandal.

BORAGINEÆ.

(*96*) *Cordia Myxa*—(Deciduous tree).—Dr. Barber has examined sandal haustoria on its roots and found them penetrating to the woody cylinder. I have not seen its attacked roots. Its value as a nurse has to be ascertained by further examination in the field.

(*97*) *Ehretia lævis*—(Deciduous tree).—I have seen small roots of this species attacked by sandal roots; the haustoria on them were

small but hard and not numerous. As it occurs in sandal areas and yields small timber and firewood, its association with sandal will be advantageous.

BIGNONIACEÆ.

(*98*) *Tecoma Stans*—(Almost evergreen shrub).—Dr. Barber examined sandal haustoria on its roots under the microscope and appears to have found them penetrating into the woody cylinder. I have not seen its attacked roots. Being an exotic in sandal areas and not of much economic value, it may not be worth introduction to such areas.

(*99*) *Kigelia pinnata*—(Deciduous tree).—The same authority has found the roots of this species attacked by sandal and the haustoria not only sucessfully penetrating the woody tissue of the host, but completely devouring it in small roots. Being a quick growing plant under varying conditions, its association with sandal may prove very useful.

ACANTHACEÆ.

(*100*) *Strobilanthes cuspidatus*—(Evergreen shrub).—This low shrub is pretty largely attacked by sandal in its early stages of growth; plates illustrating its root-attachment to sandal roots are published in the September number of the Indian Forester, Volume XXIX.

(*101*) *Adhatoda Vasica*—(Evergreen shrub).—I found this species largely attacked; the haustoria were numerous, small and woody; from the haustorial scars it appeared that penetration had been effected; the haustoria were prominently high; this species occurs commonly in cool localities in the habitat of sandal. Plate VI is a drawing of the roots examined by me.

(*102*) *Blepharis boerhaaviæfolia*—(Evergreen herb).—
(*103*) *Ruellia prostrata*—(Evergreen herb).—
} I have not seen their affected roots, but Dr. Barber has examined sandal haustoria on them and found them penetrate to the wood of the host.

VERBENACEÆ.

(*104*) *Lantana Camara*—(Deciduous shrub).—This species is very extensively affected and numerous haustoria of medium size

are found on its roots in the vicinity of sandal trees; penetration is easily effected into the wood of the host. It is a very good host for the sandal, but its exclusiveness and gregariousness kill out all other species of herbs and shrubs and prevent tree species thriving in its midst; this appears to be a danger to the sandal tree in its later stages of growth when the *Lantana* by itself cannot furnish all the nutriment that its guest requires while there are no other species to help the latter. The "spike" disease seems to have been first observed in sandal trees growing amidst the *Lantana* and it is a question still to be answered whether this species is or is not responsible for the appearance of that fell disease.

(*105*) *Tectona grandis*—(Deciduous tree).—In nursery experiments[1] I have found sandal seedlings forming root-attachments with teak seedlings and thriving fairly well in their company, but I have not examined teak roots close to sandal trees *in nature*. This requires further investigation in the field.

(*106*) *Premna tomentosa*—(Deciduous shrub or small tree).—I have found only one haustorium at the point of attachment between sandal and this species in the single specimen examined; but the sandal rootlet trailed along the host's root for a short length. Further examination of attacked roots is necessary to determine its utility as a nurse.

(*107*) *Vitex Negundo*—(Deciduous shrub).—Its roots were found very extensively attacked, even a thick tap-root being almost completely covered with living haustoria and scars of withered ones; examination of some of them under the microscope showed penetration to the woody cylinder. This seems to be an excellent nurse for sandalwood. In the roots examined the haustoria were large and flat and brownish in colour.

(*108*) *Vitex altissima*—(Deciduous tree).—I found small roots of this species attacked moderately and the haustorial scars on the roots examined exposed the woody tissues of the host to view; the haustorium was slightly above medium size. It is commonly met with in the plains and hills in sandal areas and being also a good timber tree its association with sandal is doubly advantageous.

(*109*) *Stachytarpheta indica*.—This is one of the species the roots of which were found by Dr. Barber to have been attacked by sandal roots. No further information is available.

[1] My "Notes on Sandal."—Indian Forest Records, Volume II, Part III.

Amarantaceæ.

(*110*) *Achyranthes aspera*—(Deciduous shrub).—On the tap-root of a small plant I found three living haustoria and three scars with a sandal rootlet attached to one of the former. The haustoria were small but hard and the scars showed penetration of the haustoria to the woody cylinder. Being an undershrub it is not of much importance except as a nurse for young sandal.

(*111*) *Pupalia atropurpurea.*—Sandal haustoria on its roots were examined by Dr. Barber who found them penetrating its woody tissue. It is a herb which may be useful as a nurse for young sandal.

Laurineæ.

(*112*) *Alseodaphne semicarpifolia*—(Evergreen tree).—On the tap-root of a young plant numerous scars of sandal haustoria were found; they were larger than of medium size and showed up the inner wood to view. This species is only occasionally met with above 3,000 feet on the Javadies and Yelagiries of the Salem District and yields small timber. It seems to be a fairly good nurse for sandal.

(*113*) *Litsæa zeylanica*—(Evergreen tree).—On a thick tap-root and its branches a number of haustorial scars, some of them pretty large and deep, were found; the root was dug up close to a sandal tree, but no living haustoria were seen on it; the scars exposed the inner wood to view. This species is very commonly found in sandal tracts above 2,000 and up to 5,000 feet in the Salem District and is evidently a good nurse for sandal.

On the Thirumalai Hill in Trevandrum I found a number of living sandal haustoria on the roots of this species at an elevation of 400 feet above sea-level.

Santalaceæ.

(*114*) *Santalum album*—(Evergreen tree).—Self-attachments between sandal roots are frequently met with even when other species exist plentifully. The haustoria and scars are pretty large and the former woody; in some cases the attacked root is flattened out at the points of attack. How such self-attack helps the trees is not clear; but perhaps where a sandal tree is in the vicinity of other species while another sandal is far away from them but

within reach of its own kind, this peculiarity will help it to procure its nourishment through its own kind.

EUPHORBIACEÆ.

(115) Cleistanthus collinus—(Deciduous tree).—In nursery experiments sandal seedlings were found to establish root-connections with seedlings of this species and to thrive very well in their company.[1] I have not examined its attacked roots in nature. It yields good small timber besides being a good nurse for sandal and occurs in sandal tracts very commonly, especially in plain forests.

(116) Jatropha gossypifolia—(Almost evergreen shrub).—Its roots are attacked by sandal and the haustoria penetrate to the wood. It is not commonly met with in sandal tracts in the Salem and Kurnool Districts.

(117) Jatropha Curcas—(Semi-evergreen shrub).—The tap-root and its branches of a plant were found largely attacked. The sandal haustoria and the scars on them were somewhat small and the scars were deep enough to expose the inner wood. This species too is not commonly met with in sandal areas.

(118) Acalypha fruticosa—(Evergreen herb).—The tap-root of a small plant and its rootlets were found covered with a number of sandal haustoria; they were small but hard. Plate VII is a drawing of the plant examined.

(119) Acalypha indica—(Almost evergreen shrub).—On the roots of a plant examined there was only one sandal haustorium and an elongated scar resembling that of a fallen off haustorium; the haustorium was much larger than those found in the above species and hard; Dr. Barber examined the sandal haustoria on its roots under the microscope and found them penetrating the wood.

(120) Acalypha sp.—(Garden).—Dr. Barber found sandal haustoria on its roots; I have not seen its affected roots.

(121) Mallotus philippinensis—(Evergreen tree).—I found a root of this extensively covered with large and deep scars of sandal haustoria exposing the inner wood; a few of the scars had been covered over with callus growth. It appears to be a good nurse although its occurrence in sandal areas is somewhat restricted. It yields small timber and the Kamela dye and as such will be more useful when encouraged as an associate of sandal.

[1] My "Notes on Sandal."—Indian Forest Records, Volume II, Part III.

(*122*) *Flueggia Leucopyrus*—(Shortly deciduous shrub).—Dr. Barber examined sandal haustoria on this species; I have not seen its affected roots. As it is not uncommon in the natural habitat of sandal, its utility as a host requires further investigation.

Urticaceæ.

(*123*) *Holoptelea integrifolia*—(Deciduous tree).—A long root of this tree was covered with a number of scars of sandal haustoria: they were pretty large and deep, in some cases revealing the inner wood of the host; a thin dark coloured cork-like layer covered over the surface of the scars; no living haustoria were found. It is commonly found in sandal tracts and being a timber tree may be encouraged as a nurse for sandal.

(*124*) *Cudrania javanensis*—(Shortly deciduous climbing shrub).—A root of this was found covered with a number of scars of sandal haustoria, but no living haustoria were found. The root collected having been lost I am unable to give further particulars.

(*125*) *Streblus asper*—(Evergreen tree).—I found the tap-root and rootlets of this species very largely attacked, and numerous attachments formed. Plate VIII is a drawing of the root examined, but it does not show a number of rootlets covered with haustoria as they were clipped off for convenience of drawing. The haustoria were of medium size but hard and woody. This seems to be a very good host for sandal; it occurs in sandal tracts but confined more to cool and moist localities.

(*126*) *Ficus bengalensis*—(Deciduous tree).—Small rootlets of this tree were found covered with small whitish brown haustoria: I have not examined larger roots. It will probably be found to be a tolerably good host, but I have not seen sandal trees in its proximity in the sandal areas, though I have seen a few saplings in its neighbourhood in a compound at Tirupatur (Salem).

(*127*) *Ficus mysorensis*—(Deciduous tree).—Roots of this species also are attacked, but the haustoria are small and rather far apart; haustoria examined under the microscope showed penetration into the woody cylinder. I have seen sandal trees flourishing in its vicinity and therefore think that it would be a good host for that species.

(*128*) *Ficus religiosa*—(Deciduous tree).—Dr. Barber has examined under the microscope sandal haustoria on its roots and

found them penetrate to the wood; I have not seen its attacked roots. It is not very commonly found in sandal tracts.

(*129*) *Artocarpus integrifolia*—(Evergreen tree).—A root of this species was found close to a sandal tree on Thirumalai Hill in Trevandrum and it bore traces of sandal attack; the haustoria were flat, membranous and dead; this species does not seem to be a good host—further observation is required.

CASUARINEÆ.

(*130*) *Casuarina equisetifolia*—(Evergreen tree).—This is said to be a very good nurse for sandal up to a certain age. Dr. Barber has examined sandal haustoria on its roots. I have not seen its affected roots. If associated with other longer-lived species, it might prove a very good nurse for sandal.

SALICINEÆ.

(*131*) *Salix tetrasperma*—(Deciduous tree).—I found dead sandal haustoria on small roots of this tree; they were membranous and small; I have seen sandal trees growing in its company at Bangalore, but how far it influences its growth could not be ascertained, as there were other species growing with it and no living haustoria were seen on its roots.

II.—MONOCOTYLEDONS.

HÆMODORACEÆ.

(*132*) *Sansevieria zeylanica*—(Evergreen shrub).—I found 2 sandal haustoria and a scar on a root of this; they were small; whether penetration had been effected could not be ascertained. Dr. Barber examined sandal haustoria on its roots under the microscope and found formation of protective corky layers on the cortex before the haustorial sucker reached the vascular bundles, thus effectively cutting it off from the latter.

AMARYLLIDEÆ.

(*133*) *Agave Vera-Cruz*—(Evergreen shrub).—Dr. Barber examined sandal haustoria on the roots of this species and found the sucker cut off from the vascular bundles of the host by the formation

of protective corky layers in the host's cortex. I believe very young and tender roots are successfully penetrated though in well developed roots the vascular bundles are not reached. Yet I have found young sandal flourishing in aloe hedges without other hosts near by.

(*134*) *Fourcroya gigantea*—(Evergreen shrub).—I found its roots pretty largely attacked but the haustoria were small and membranous. When numerous haustoria were examined under the microscope, not a single case of successful penetration was noticed owing to the existence of a thick ring of sclerotic cells in the inner living cortex. Yet I have seen pretty vigorous growth of sandal trees in pure hedges of this species. Unless it be that the sandal obtains its nutriment from the dead and living barks (red-coloured) it is difficult to explain the healthy and vigorous growth of the sandal plants in the *Fourcroya* hedges.

LILIACEÆ.

(*135*) *Asparagus racemosus*—(Deciduous shrub).—I have not seen affected roots of this species. Dr. Barber has examined sandal haustoria on its roots and found them penetrate the bark though not the vascular bundles.

(*136*) *Dracæna* (*garden*)—(Evergreen shrub).—Sandal haustoria on this species have been examined by Dr. Barber but the result is not clearly stated. Its utility as a nurse requires further investigation.

PALMEÆ.

(*137*) *Phœnix sylvestris*—(Evergreen tree).—Its roots are attacked pretty largely; the sandal haustoria and their scars are medium-sized, but the former are membranous and soft; in the roots examined although the scars were deep, it did not appear that the vascular bundles had been penetrated. I have seen sandal trees growing well in the vicinity of the date palm and presumably they get some portion of their nourishment from it. Haustoria on tender and unlignified roots should be examined under the microscope to see whether penetration is effected.

(*138*) *Cocos nucifera*—(Evergreen tree).—I have seen sandal haustoria formed on its roots at Salem, Pondicherry and Bangalore.

Their examination under the microscope showed no penetration into the vascular system of the host although numerous haustoria on well-developed roots were examined. I was not able to secure them on tender and unlignified rootlets; further examination of such roots and rootlets is necessary.

CYPERACEÆ.

(*139*) *Cyperus rotundus*—(Evergreen).—Dr. Barber found roots of this species attacked and examined sandal haustoria on their roots. I have not seen affected roots of it.

GRAMINEÆ.

(*140*) *Cynodon dactylon*—(Evergreen).—I found its root attacked by a tiny thread like sandal rootlet and two minute haustoria formed. This grass may help in nourishing young sandal seedlings.

(*141*) *Eleusine ægyptiaca* (*indica*)—Evergreen).—Young sandal seedlings form root-attachments with this grass and their haustoria are minute.

(*142*) *Bambusa arundinacea*—(Deciduous).—Sandal forms numerous root-attachments with this species and thrives very well in its vicinity. I have found this at Bangalore and in the Salem sandal areas. The haustoria are of medium size or smaller, hard and woody unlike those on palm roots and in the majority of cases compound. Haustoria on young roots were found to have penetrated the vascular system, while those on older and bigger roots had not pierced through the sclerotic ring; in one case there were 12 attempts made by one haustorium to effect penetration as revealed by the number of haustorial cortical folds. Although it is a very good host, there is danger of sandal plants caught up in a clump being squeezed by the bamboo culms and suppressed by their heavy cover overhead.

(*143*) *Bambusa auriculata*—(Deciduous).—Dr. Barber mentions this among the sandal hosts in Appendix I but does not say whether he found any root-attachments. I have not seen this species attacked.

(*144*) *Ochlandra Rheedii*—(Evergreen).—The roots of this species are attacked but not so extensively as those of the bamboo. On a rhizome about a foot long with numerous roots there was only

one compound haustorium on one of the roots. Dr. Barber found no successful penetration of the haustorium into the vascular system of the root in his examination under the microscope. It is doubtful whether this species is of any service to the sandal as a nurse.

11. The species of plants described above are not the only ones which are associated with sandal. They merely represent those whose roots have been examined hitherto and found to be attacked by sandal roots. Numerous other species of plants are found associated with it in its natural habitat and their roots still await examination in order to ascertain whether and, if so, to what extent sandal attacks and forms root-connections with them. A list of such plants—taken from the appendices to Dr. Barber's "Studies in Root-parasitism—The Haustorium of Santalum album," Volume I, No. I, Part II, of the Memoirs of the Department of Agriculture in India, and from my "Tirupattur Sandalwood Working Plan" published in the Proceedings of the Board of Revenue, Madras, Forest No. 172, dated 20th August 1904, and from other sources—is appended to this note. It is believed that this list is not exhaustive and that there are many other associates of sandal which have to be ascertained by inspections of the sandal tracts in the various parts of India where it occurs.

12. Mr. A. W. Lushington, Conservator of Forests in the Madras Presidency, is of opinion that evergreen plants are probably better hosts of sandal and that investigations in this direction will prove very useful. Judging from the fact that 82 out of the 144 species of host plants already examined and described above are evergreen or nearly so, I am inclined to agree with him. This point deserves to be studied further.

He also suggests for investigation the question whether essential oil-bearing or balsam-producing species have any special effect upon the sandal, and, if so, to what extent. He writes to me that, in May 1908, he observed in Ramundrug in the Bellary District sandal plants growing on or near evergreen species remained evergreen while those growing on deciduous species became deciduous and were just putting forward new young leaves after losing all their old leaves. I have also observed a tendency in the sandal to become deciduous in very dry localities in the Mysore Province, Salem and Kurnool Districts, especially where other species of plants associated with it are few and are deciduous.

At the request of Mr. Lushington, the District Forest Officer of North Arcot had all trees and shrubs growing within a radius of 25 feet of 90 healthy sandal trees counted with the following result. The average number of trees and shrubs within this space was found to be 17:—

1. Canthium parviflorum and didymum	3·4
2. Vitex altissima	1·6
3. Acacia pennata	1·6
4. Phyllanthus	1·6
5. Zizyphus Œnoplia	1·4
6. Mallotus philippinensis	1·0
7. Maba buxifolia	0·8
8. Diospyros chloroxylon	0·7
9. Strychnos Nux-vomica	0·7
10. Schleichera trijuga	0·6
11. Other minor shrubs and creepers	3·6
	17·0

From this enumeration, the District Forest Officer draws the conclusion that *Canthium parviflorum* and *Canthium didymum* are convenient associates of sandal on the Javadies. On this Mr. Lushington remarks that as suspected by him sandal strongly favours evergreen scrub growth, the majority of the hosts in the above case being of that nature.[1]

13. No conclusion can be drawn from the host plants described in the foregoing pages as to the influence exerted on the growth of sandal by the species which produce or contain fixed or essential oils or balsam, for, there are only about 25 of such species among the 144 described and nothing definite is known yet of the effect of each of them on sandal. This question merits further investigation and research.

14. It has been suggested to me that a classification of the host plants already examined and dealt with in the foregoing pages into "Good," "Medium" and "Indifferent" hosts will be desirable and useful. Although this suggestion is a good one, still, I refrain from attempting a classification such as suggested, as it seems to me premature to do so on the basis of what is recorded above as a result of only a single observation in many cases, until it is verified and confirmed. To those who wish to know which of the species described by me are good hosts, it would not be tedious to refer to the description and find out the information they require.

[1] Ref. on C. No. 116, dated 17th January 1910, of the Conservator of Forests, Northern Circle, Madras.

APPENDIX.

List of Associates of the Sandal tree in its natural habitat and elsewhere.

Names marked* indicate species with whose roots Sandal has been ascertained to form root-attachments.

Serial No.	Botanical name.	Vernacular name.
	ANONACEÆ.	
1	* Polyalthia longifolia . .	Asoka. Tam.
2	* Goniothalamus wynaadensis .	Pulichan sedi. Tam.
3	* „ sp. . .	Kakanan sedi. Tam.
4	* Artabotrys odoratissimus . .	Monoranjini. Tam.
5	„ biglandulosa . .	......
6	* Anona squamosa . . .	Seetha sedi.
	MENISPERMACEÆ.	
7	* Tinospora cordifolia . . .	Amrithavalli. Tam.
8	Cocculus villosus . . .	......
	CAPPARIDEÆ.	
9	* Capparis zeylanica . . .	Totli. Tam.
10	„ sepiaria . . .	Kokkimullu. Tam.
11	„ divaricata . . .	Touratti. Tam.
12	„ horrida . . .	Atanday. Tam.
13	Cadaba indica	Vilithikeeray. Tam.
	BIXINEÆ.	
14	Cochlospermum Gossypium . .	Kattuparuthi. Tam.
15	Flacourtia sepiaria . . .	Goddumundi. Tam.
16	„ Ramontchi . .	Mundi. Tam.
17	Hydnocarpus Wightiana . .	Maravetti. Mal.
	GUTTIFERÆ.	
18	Calophyllum Inophyllum . .	Punna. Mal.

List of Associates of the Sandal tree, etc.—*contd.*

Serial No.	Botanical name.	Vernacular name.
	MALVACEÆ.	
19	* Thespesia populnea . . .	Puvarasa. Mal. and Tam.
20	* Sida carpinifolia . .	......
21	* ,, rhombifolia . . .	......
22	* Gossypium arboreum .	Paruthi. Tam.
	STERCULIACEÆ.	
23	* Pterospermum Heyneanum .	I olavu. Tam.
24	* ,, suberifolium .	Thaday. Tam.
25	* Sterculia alata	Thondi. Mal.
26	* Guazuma tomentosa . . .	Thenpuchi. Tam.
	TILIACEÆ.	
27	* Berrya Ammonilla . . .	Thirukanamalay. Tam.
28	* Grewia hirsuta . . .	Tellajana. Tel.
29	* ,, tiliæfolia . .	Thadachi. Tam.
30	* ,, sp.	Pannipudukken. Tam.
31	,, Microcos . . .	Kottaisedi. Mal.
	LINEÆ.	
32	Erythroxylon monogynum . .	Semlichan. Tam.
	MALPIGHIACEÆ.	
33	Hiptage Madablota . . .	Kurukuthi. Tam.
	GERANIACEÆ.	
34	* Averrhoa Carambola . . .	Pulichi. Mal.
	RUTACEÆ.	
35	Murraya exotica . . .	Vangārai ; Konji. Tam.
36	,, Koenigii . . .	Karuveppelia. Tam.

List of Associates of the Sandal tree, etc.—*contd.*

Serial No.	Botanical name	Vernacular name.
	RUTACEÆ—*contd.*	
37	* Clausena indica . . .	Naua ; Karuveppalai. Tam.
38	* Limonia acidissima . . .	Naivela. Tam.
39	Feronia Elephantum . .	Velā. Tam.
40	* Toddalia aculeata . . .	Katmolagu Tam.
41	Atalantia monophylla . .	Kuruthan, Katelimichan. Tam.
42	* Citrus Aurantium . . .	Kitchli. Tam.
	SIMARUBEÆ.	
43	* Ailanthus excelsa . . .	Perumaram. Tam.
44	Balanites Roxburghii. . .	Nanjunda. Tam.
	BURSERACEÆ.	
45	* Protium caudatum . . .	Kiluvai. Tam.
46	Garuga pinnata . . .	Arunelli. Tam.
47	Boswellia serrata . . .	Sambrani ; Vellai-Kungiliyam. Tam.
	MELIACEÆ.	
48	* Melia Azadirachta . . .	Vepa. Tam.
49	* Cipadessa fruticosa . . .	Sevattai. Tam.
50	Chickrassia tabularis . . .	Selungachi. Tam. Gantumali. Kan.
51	Cedrela Toona	Madagarivembu. Tam.
52	Chloroxylon Swietenia . .	Borasu. Tam.
	OLACACEÆ.	
53	* Cansjera Rheedii . . .	......
	CELASTRACEÆ.	
54	* Celastrus paniculata . . .	......
55	Gymnosporia montana . .	Kattangi. Tam.
56	* Elæodendron Roxburghii . .	Keeri ; Irgulli. Tam.

List of Associates of the Sandal tree, etc.—*contd.*

Serial No.	Botanical name.	Vernacular name
	RHAMNEÆ.	
57	* Ventilago madraspatana . .	Vembadan. Tam.
58	* Zizyphus Œnoplia . . .	Surimullu. Tam.
59	,, Jujuba . . .	Elanthai. Tam.
60	* ,, rugosa . . .	Kat-elanthai. Tam.
61	,, xylopyrus . .	Nai-elanthai. Kottai. Tam.
62	Scutia indica	Konkimullu. Tam.
	SAPINDACEÆ.	
63	Cardiospermum Halicacabum .	Modakathan. Tam.
64	Dodonæa viscosa . . .	Velari. Tam.
65	* Schleichera trijuga . . .	Poovan. Mal.
66	Sapindus Mukorossi . . .	Manipungan; Poochukottai. Tam.
67	Erioglossum rubiginosum . .	Korali, Manipungan. Tam.
	ANACARDIACEÆ.	
68	Odina Wodier	Oodian. Tam.
69	Buchanania latifolia . .	Sarai. Tam.
70	* Mangifera indica . .	Mavu. Mal.
71	Semecarpus Anacardium .	Charu. Mal.
72	* Anacardium occidentale . .	Munthiri. Tam.
	MORINGACEÆ.	
73	Moringa pterygosperma . .	Muringa. Mal.
	CONNARACEÆ.	
74	Connarus monocarpus . .	Kureel. Mal. (With sandal on Thirumalai and Jasper Hill, Trevandrum.)

List of Associates of the Sandal tree, etc.—*contd.*

Serial No.	Botanical name.	Vernacular name.
	LEGUMINOSÆ.	
75	Erythrina stricta	Mullu-marukku. Tam.
76	Butea frondosa	Murukkan. Tam.
77	* Dalbergia scandens	Konilkodi. Tam.
78	* „ Sissoo	Gette.
79	* „ paniculata	Pachalai. Tam.
80	* „ latifolia	Iruvadi. Tam.
81	„ lanceolaria	Gattipachalai. Tam.
82	Pterocarpus Marsupium	Vengai. Tam.
83	* Pongamia glabra	Pungom. Tam.
84	* Castanospermum australe	......
85	* Clitoria Ternatea	......
86	* Dolichos Lablab	Sittavarai. Tam.
87	* Canavalia ensiformis (?) *var.* Virosa.	Kattuthamattai. Tam.
88	* Cæsalpinia Bonducella	Getchakai. Tam.
89	„ sepiaria	Kuruttu-gajjigai. Kan.
90	* Peltophorum ferrugineum	....
91	* Pterolobium indicum	Karindu. Tam.
92	Parkinsonia aculeata	Parengivelan. Tam.
93	* Tamarindus indica	Puli. Mal.
94	Cassia Fistula	Konnai. Tam.
95	* „ siamea	Roattu-konnai ; Manjakonnai. Tam.
96	* „ auriculata	Avarom.
97	Bauhinia racemosa	Sittacha.
98	* Adenanthera pavonina	Anaikundumani. Tam.
99	Prosopis spicigera	Parambai. Tam. (Pumgamadavu Reserve, Salem District.)
100	* Parkia biglandulosa	Mavu kaimarom.
101	* Leucæna glauca	Tagaraimarom.
102	Acacia arabica	Karuvelom.
103	„ leucophlœa	Velvélam.
104	„ Catechu	Karungali.
105	„ Sundra	Karungali.
106	* „ Suma	Mugali. Kan.
107	* „ cæsia (Intsia)	Seengai. Tam.
108	* „ pennata	......
109	„ ferruginea	Seemai velvelom. Tam.
110	* „ concinna	Seekai. Tam.
111	* Albizzia odoratissima	Selai ; Kal-turinji. Tam.
112	* „ Lebbek	Kat-vahai. Tam.
113	* „ amara	Turinji ; Oongil. Tam.
114	* Pithecolobium dulce	Korukkapuli. Tam.
115	* „ Saman	......

List of Associates of the Sandal tree, etc. —*contd.*

Serial No.	Botanical name.	Vernacular name.
	COMBRETACEÆ.	
116	Terminalia belerica . . .	Thani. Tam.
117	* ,, Chebula . . .	Kadukai. Tam.
118	* ,, Arjuna . . .	Attumaddi. Tam.
119	,, paniculata . .	Maruthi-Mal; Puluvé. Tam.
120	* Combretum ovalifolium .	Vennangukodi. Tam.
121	Anogeissus latifolia . . .	Namai; Vekkali. Tam.
	MYRTACEÆ.	
122	* Eugenia jambolana . . .	Naga. Tam.
123	* Psidium Guayava . . .	Goyya. Tam.
124	* Eucalyptus globulus . . .	......
125	Careya arborea . . .	Amai-marom. Tam. Pezhu. Mal
	MELASTOMACEÆ.	
126	Memecylon edule . . .	Kassan. Tam.
	LYTHRACEÆ.	
127	Lagerstrœmia lanceolata . .	Ventekku. Tam.
128	Lawsonia alba	Maruthani. Tam.
	SAMYDACEÆ.	
129	* Casearia tomentosa .	Kottu kóvai; Gutti. Tam.
	CUCURBITACEÆ.	
130	* Cucurbita dioica . .	Kóvai. Tam.
	BEGONIACEÆ.	
131	* Begonia (garden) . . .	.....

List of Associates of the Sandal tree, etc.—*contd.*

Serial No.	Botanical name.	Vernacular name.
	CACTEÆ.	
132	* Opuntia Dillenii	Sappathekalli. Tam.
	ARALIACEÆ.	
133	* Heptapleurum verticillatum	......
134	* „ venulosum	Velátta. Tam.
135	* Panax (garden)	......
	CORNACEÆ.	
136	* Alangium Lamarckii	Alinji. Tam.
	RUBIACEÆ.	
137	Stephegyne parvifolia	Nirkadambi. Tam.
138	* Webera corymbosa	Therani. Tam.
139	* Randia dumetorum	Karay. Tam.
140	„ uliginosa	Marakaray. Tam. Godukarai.
141	Canthium didymum	Nekkani. Tam.
142	„ parviflorum	Nalla karai. Tam.
143	Ixora parviflora	Kora, Shulauda. Tam.
144	„ coccinea	Thetti Mal. (Found with sandal on Jasper Hill, Trevandrum.)
145	* Pavetta indica	Pavattai. Tam.
146	* Marinda citrifolia	Nona. Tam.
	PLUMBAGINEÆ.	
147	* Plumbago zeylanica	Chitramulam. Tam.
	MYRSINEÆ.	
148	* Ardisia humilis	Maniputtan. Tam.

List of Associates of the Sandal tree, etc.—*contd.*

Serial No.	Botanical name.	Vernacular name.
	SAPOTACEÆ.	
149	* Mimusops indica . . .	Magadom. Tam.
150	,, hexandra . . .	Pālai. Tam.
151	Bassia longifolia . . .	Iluppai. Tam.
	EBENACEÆ.	
152	Diospyros Chloroxylon . .	Karuvakkanai. Tam.
153	,, montana . . .	Velvakkanai. Tam.
154	* ,, Kanjilali . . .	Nótchikonnai. Tam. (Found on Kumbugudi Plateau.)
155	,, Tupru . . .	Tübaray. Kan.
156	,, melanoxylon .	Karunthumbi. Tam.
157	Maba buxifolia . . .	Irumbuli. Tam.
	OLEACEÆ.	
158	* Jasminum malabaricum . .	Mullai. Tam.
159	* ,, rigidum . . .	......
160	* Olea dioica . . .	Kānaiporumbalu. Tam.
161	* Linociera malabarica . . .	Porumbalu. Tam.
	SALVADORACEÆ.	
162	* Azima tetracantha . . .	Sangansedi. Tam.
	APOCYNACEÆ.	
163	* Carissa Carandas . . .	Kla. Tam.
164	,, spinarum . . .	Kila; Kla. Tam.
165	* Wrightia tinctoria . . .	Veppalé. Tam.
166	,, tomentosa . . .	Sonaiveppale. Tam.
	ASCLEPIADACEÆ.	
167	* Sarcostemma brevistigma . .	Eripulinji. Tel.
168	* Dregea volubilis . . .	......
169	* Heterostemma sp. (?) . .	Karalankodi. Tam.
170	Boucerosia umbellata . .	Enakundelekommu. Tel.

List of Associates of the Sandal tree, etc.—*contd.*

Serial No.	Botanical name.	Vernacular name.
	LOGANIACEÆ.	
171	Strychnos Nux-vomica	Ettimarom. Tam.
172	„ potatorum	Thethankottai. Tam.
	BORAGINEÆ.	
173	* Cordia Myxa	Jollai. Tam.
174	„ Macleodii	Pallen-teku. Tam.
175	* Ehretia lævis	Polimiri. Tel.
	BIGNONIACEÆ.	
176	* Tecoma Stans	......
177	* Kigelia pinnata	......
178	Millingtonia hortensis	Maramalli. Tam.
	ACANTHACEÆ.	
179	* Ruellia prostrata	......
180	* Strobilanthes cuspidatus	Sirukurungan. Tam.
181	* Adhatoda Vasica	Adatoda. Tam.
182	* Blepharis boerhaaviæfolia	......
183	Meyenia (garden)	......
	VERBENACEÆ.	
184	* Lantana Camara	Béligida. Kan.
185	* Stachytarpheta indica	......
186	* Vitex Negundo	Vella notchi. Tam.
187	„ alata	......
188	* „ altissima	Myladi Tam.
189	„ pubescens	Myladi. Tam.
190	* Tectona grandis	Theku. Tam.
191	Clerodendron infortunatum	Peruvelom. Mal
192	Gmelina arborea	Kumbilam. Tam.
193	„ asiatica	Kumbilakodi. Tam.
194	* Premna tomentosa	Podanganari. Tam.
195	„ integrifolia	Minnay. Tam.

List of Associates of the Sandal tree, etc.—*contd.*

Serial No.	Botanical name.	Vernacular name.
	LABIATÆ.	
196	Coleus (garden) . . .	......
197	* Mentha piperita . . .	Pudeena. Kan.
	AMARANTACEÆ.	
198	* Achyranthes aspera	Nayuri. Tam.
199	* Pupalia atropurpurea . . .	.....
	LAURINEÆ.	
200	* Alseodaphne semicarpifolia . .	Buddasedi. Tam.
201	,, umbelliflora . .	......
202	* Litsæa zeylanica . . .	Sirupanjettai. Tam.
203	,, tomentosa . .	Peruppanjettai. Tam.
	HERNANDIEÆ.	
204	* Gyrocarpus americanus (Jacq.) .	Vellai-thanakku. Tam.
	ELÆAGNACEÆ.	
205	Elæagnus umbellata . . .	Kulari. Tam.
	SANTALACEÆ.	
206	* Santalum album . .	Sandanom. Tam.
	EUPHORBIACEÆ.	
207	Euphorbia pilulifera	.....
208	* Cleistanthus collinus . . .	Woddan. Tam.
209	Flueggia microcarpa . . .	Poola. Tam
210	* ,, Leucopyrus .	Veppüla. Tam.
211	Phyllanthus reticulatus	Pulichinta. (Tel.) Kurnool.
212	,, Emblica .	Nelli. Tam.
213	* Jatropha Curcas . .	Kattu-amanakku. Tam.

List of Associates of the Sandal tree, etc.—*contd.*

Serial No	Botanical name.	Vernacular name.
	EUPHORBIACEÆ—*contd.*	
214	Jatropha glandulifera . .	Kattamanakku. Tam.
215	* ,, gossypifolia . .	......
216	Givotia rottleriformis . .	Polukki. Tam.
217	Codiæum (garden) . . .	......
218	* Acalypha fruticosa . . .	Kuppamani. Tam.
219	* ,, indica . . .	Jiddu. Tam.
220	* ,, (garden) . . .	......
221	† Mallotus philippinensis . .	Tirusella. Tam.
	URTICACEÆ.	
222	* Holoptelea integrifolia . .	Avali. Tam.
223	Trema orientalis . . .	Bendai. Tam.
224	* Ficus bengalensis . . .	Ala. Tam.
225	* ,, mysorensis . . .	Goni. Kan.
226	* ,, religiosa	Arasu. Tam.
227	* Artocarpus integrifolia . .	Pila. Tam.
228	* ,, hirsuta . . .	Anjili. Mal.
229	Cudrania javanensis . . .	Achankaranai. Tam.
230	* Streblus asper	Pirayen. Tam.
	CASUARINEÆ.	
231	* Casuarina equisetifolia . .	Chowku. Tam.
	SALICINEÆ.	
232	* Salix tetrasperma . . .	Nir notchi. Tam.
	HÆMODORACEÆ.	
233	* Sansevieria zeylanica . . .	Marul. Tam.
	AMARYLLIDEÆ.	
234	* Agave Vera-Cruz . . .	Kattali. Canarese.
235	* Fourcroya gigantea . . .	......

List of Associates of the Sandal tree, etc.—*concld.*

Serial No.	Botanical name.	Vernacular name.
	LILIACEÆ.	
236	* Asparagus racemosus . . .	Sadaveri. Mal.
237	* Dracæna (garden) . . .	......
	PALMÆ.	
238	* Phœnix sylvestris . . .	Ichamarom. Tam.
239	Arenga saccharifera . . .	......
240	* Cocos nucifera	Thennamarom. Tam.
241	Caryota urens	Kundapanai. Mal.
242	„ mitis (sobolifera) . .	......
	CYPERACEÆ.	
243	* Cyperus rotundus . . .	Korai pillu. Tam.
	GRAMINEÆ.	
244	Saccharum spontaneum . .	Muddulihulla Kan.
245	Andropogon contortus . .	Gaddipul. Tam.
246	„ Schœnanthus . .	Vennhapul. Tam.
247	* Cynodon dactylon . . .	Arugampillu. Tam.
248	* Eleusine ægyptiaca . . .	......
249	* Bambusa arundinacea . .	Peruvarai. Tam.
250	* „ auriculata . . .	......
251	Dendrocalamus strictus . .	Siruvarai. Tam.
252	* Ochlandra Rheedii . . .	Nanal. Tam.

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PLATE I.

A.—root of *Thespesia populnea,* attacked by B.—a sandal root and B_1 B_1.—sandal rootlets ; a, a—cushions or tubercles of living haustoria ; b, b—scars of withered haustoria. Small dull red spots on A indicate natural warty excrescences on the roots of the host plant.

Plate I.

Engraved and Printed by The Calcutta Phototype Co.

PLATE II.

A—root of *Elæodendron Roxburghii* showing marks of attack by sandal roots. a, a—withered sandal haustoria adhering to the root; b, b—scars of fallen-off haustoria.

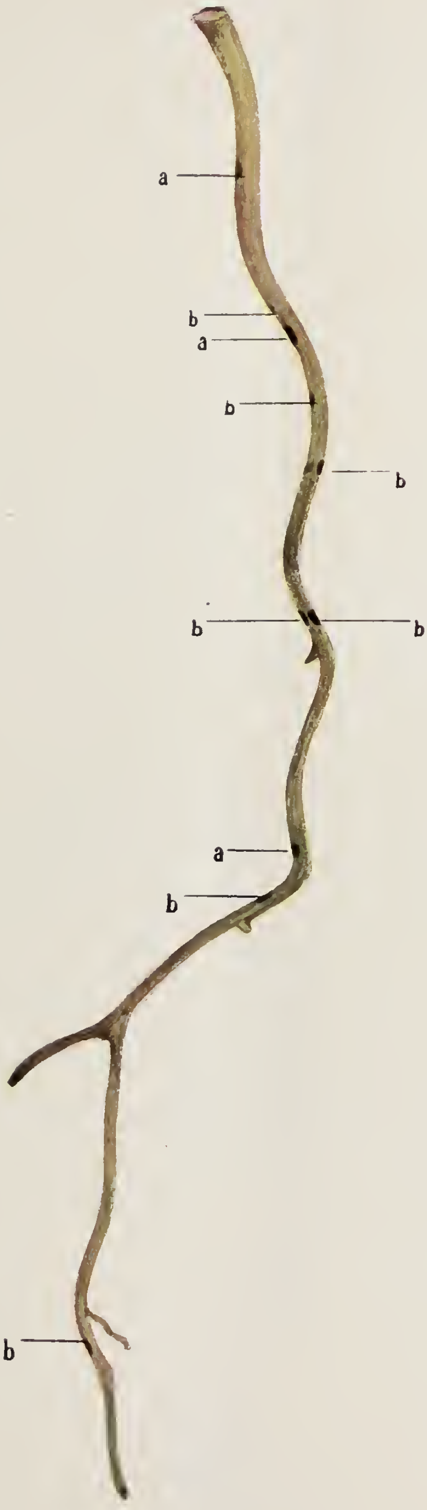
a
b
a
b
b
b
b
a
b
b

PLATE III.

Root of *Dalbergia Sissoo*—bearing marks of attacks by sandal roots.

A—root of *Dalbergia Sissoo* ; B—rootlet of sandal; a, a—scars of withered haustoria; b, b—cushions or tubercles of sandal haustoria ; b_1 b_1 small cushions of sandal haustoria on the sandal rootlet itself at points of contact with a *Thespesia* rootlet.

Plate III.

Engraved and Printed by The Calcutta Phototype Co.

PLATE IV.

Root of *Acasia Intsia*—attacked by a sandal root; illustrates how a sandal root or rootlet sometimes trails along a host-root sending down suckers into the tissues of the host without forming any visible haustorial cushions.

A is the root of *Acasia Intsia*:

B is the sandal root.

a, a—cushions or tubercles of sandal haustoria.

b, b—scars of withered haustoria.

c, c—points at which a sandal root trailing along the host-root has sent suckers into the tissues of the host without forming visible haustoria.

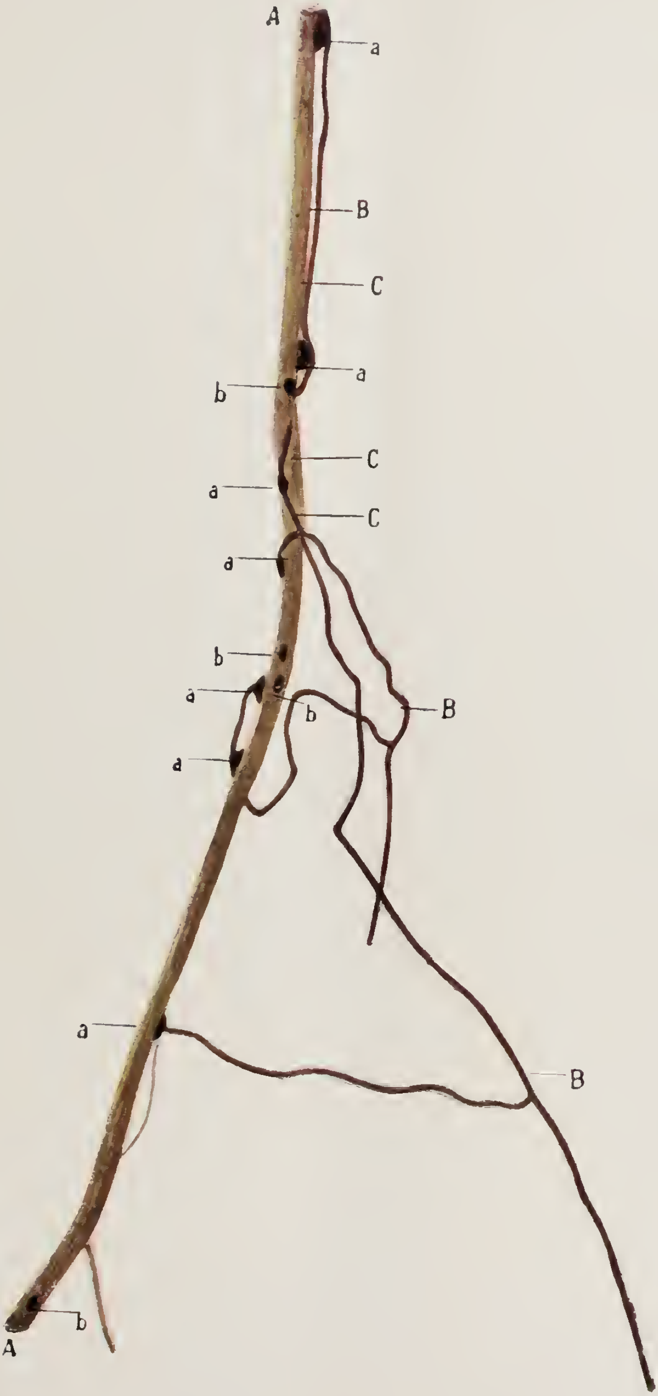

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PLATE V.

Root of *Eucalyptus globulus* A.—attacked by sandal rootlets B B : a, a—living sandal haustoria, b, b—scars of withered haustoria.

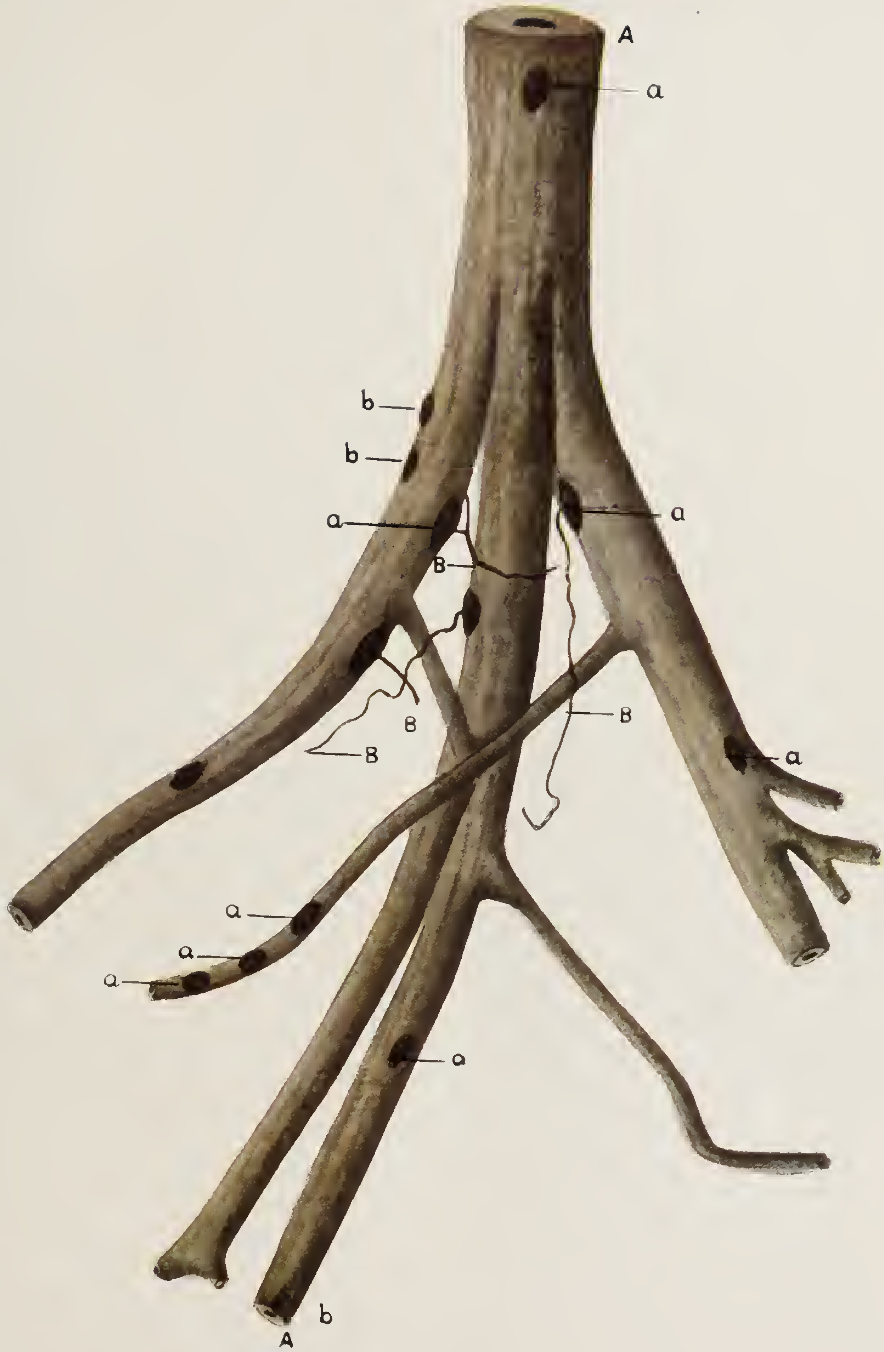

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PLATE VI.

Illustrates root attachments of sandal with the roots of *Adhatoda Vasica.*

A A—*Adhatoda Vasica* plant.

B, B – sandal root and rootlets.

a, a, a—points at which sandal rootlets are attached to the roots of the host plant.

b, b, b—cushions formed by sandal haustoria on the host.

c—cushion formed on a sandal rootlet at point of contact with another sandal rootlet.

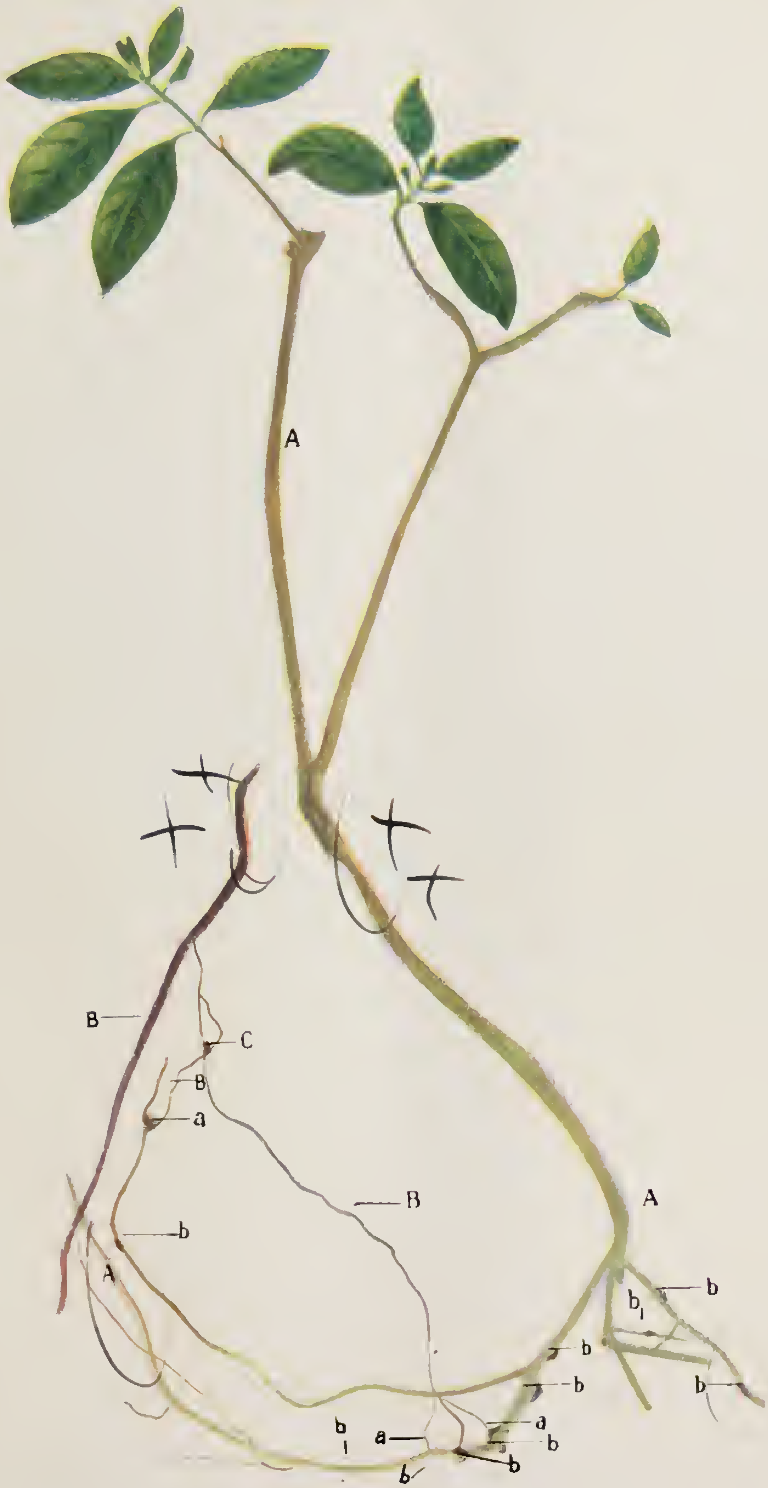

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PLATE VII.

Acalypha fruticosa plant showing tiny cushions formed by sandal haustoria
a, a, a—cushions of living sandal haustoria.

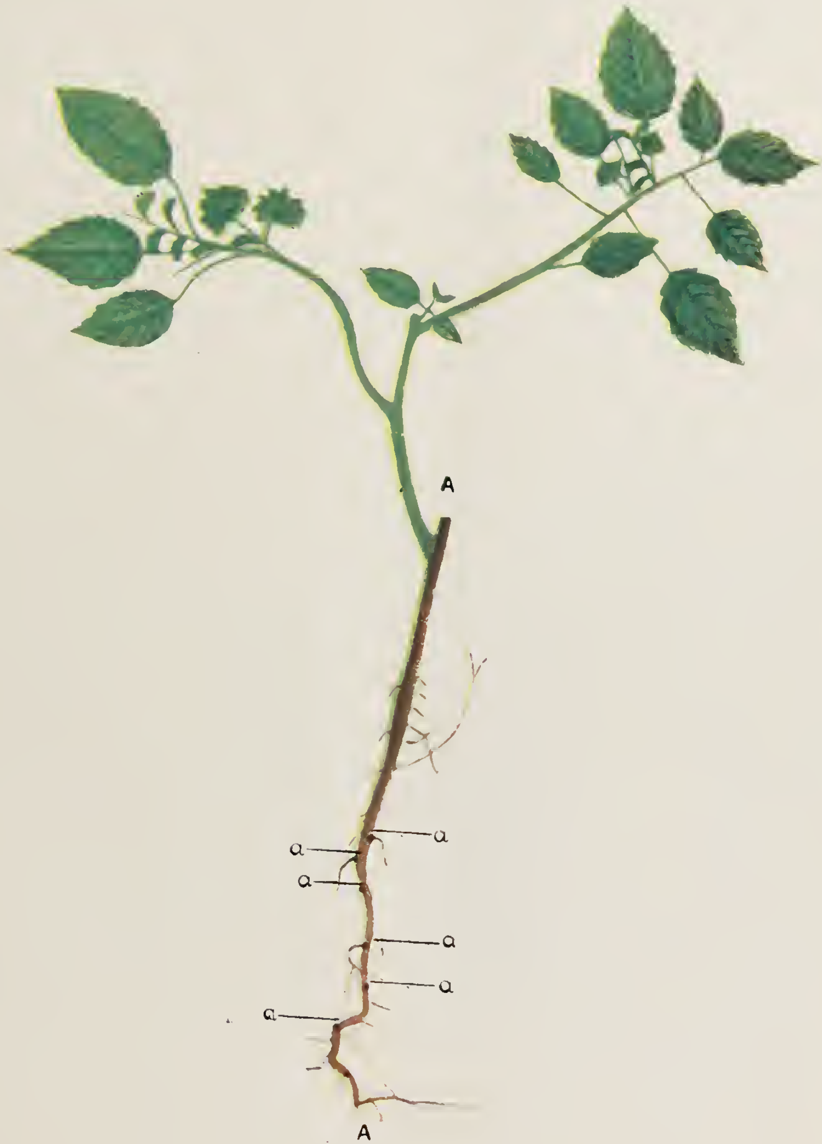

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PLATE VIII.

Illustrates attachments of sandal roots and rootlets to roots and rootlets of *Streblus asper*. (Tamil Kuttipilavu or Pirayen.)

A, A—root of *Streblus asper*; B, B—sandal root; B_1 B_1—sandal rootlets still adhering to cushions formed by sandal haustoria.

a, a—living sandal haustoria on the lateral roots of *Streblus asper*.


A
A
B
B
B
B
B1
B1
B1
B1
B1
a